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A Process for Siting Hydrocarbon Facilities on the Canadian Arctic Coast



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**A PROCESS FOR SITING HYDROCARBON FACILITIES
ON THE CANADIAN ARCTIC COAST**

by

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for the

**Environmental Strategies Directorate
Environmental Protection Service
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pour les installations servant à
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ABSTRACT

A facility siting process is presented which is intended to involve participants from industry, government and the public, in a type of advocacy approach to the choice of development sites. The process outlines a series of decisions to be made by these representatives, in an attempt to make the assumptions and decisions of siting both explicit and systematic.

Criteria developed for use in the siting process include environmental considerations only, though economic, social, engineering and other considerations would also be of importance in any siting decision. An important part of this process is that the participants develop or adopt their own criteria for assessment of siting decision.

REVIEW NOTICE

Although this report has been reviewed and approved for publication by Environment Canada and Indian and Northern Affairs Canada, the contents do not necessarily reflect the policies of these departments.

RÉSUMÉ

Dans le présent rapport, on présente un processus de sélection des emplacements destinés à l'exploitation des ressources, axé sur la participation de l'industrie, du gouvernement et du grand public. On y expose une série de décisions que doivent prendre les participants, dans le but de rendre claires et systématiques toutes hypothèses et décisions.

Les critères élaborés pour le processus sont fondés uniquement sur des considérations d'ordre environnemental, bien que les considérations économiques, sociales, techniques ou autres aient certainement leur importance dans toute décision. L'une des principales caractéristiques du processus est que les participants élaborent ou adoptent les critères qui leur conviennent pour l'évaluation des décisions concernant les emplacements.

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SUMMARY AND RECOMMENDATIONS

This report presents a methodology for siting facilities related to hydrocarbon resource development in the Canadian Arctic. The methodology draws from current US siting practices for major coastal energy facilities but recognizes the special context for siting in Canada. The criteria developed for use in siting are limited to "environmental" considerations, per the terms of reference for the study. These environmental criteria were developed based on readily available data for northern Canada and analogous parts of Alaska. Economic and engineering considerations would have to be included as well in an actual siting study. The siting process allows for incorporation of economic, facility engineering, and miscellaneous criteria in addition to those related to the natural and socio-cultural environments.

Environment Canada, because of its role in environmental assessments, and the Department of Indian and Northern Affairs, because of its mandate to control land use in northern Canada, were the principal government departments involved in this study. A more broadly composed steering committee and other reviewers assisted these departments in providing perspective on current oil and gas activities, particularly in the Beaufort Sea region, and on the applicability of the siting process and criteria to current and projected areas of exploration.

The proposed process, is structured to lead a participant to ask appropriate questions and make choices while proceeding from the initial decision to build a facility to a specific decision on a preferred site.

The five basic steps in the siting process are:

1. define the siting problem;
2. translate regional screening issues to spatial preferences;
3. select candidate areas;
4. select candidate sites from candidate areas; and
5. select preferred site(s).

The method allows technical inputs to be separated from policy inputs. In practice, the technical aspects of the siting process are performed or facilitated by a project manager and support personnel (the siting team). The decision-making participants generally provide only policy inputs in accordance with their objectives, criteria, and preferences among various trade-offs. A unique feature of the siting process

is that individual participants focus on their own objectives in a type of advocacy approach, where each participant is assured that one of the potential sites evaluated will reasonably represent his or her point of view. Consideration of diverse issues is thus insured.

The environmental criteria developed in this report fall into eight categories:

1. Terrestrial Ecology;
2. Aquatic/Marine Ecology;
3. Socio-cultural Resources;
4. Subsistence Economy Effects;
5. Hydrologic Effects;
6. Climatology;
7. Non-renewable Resources; and
8. Terrain/Land Classification.

These categories are used to organize the discussion of criteria and their application. Example criteria are listed by category in Appendix III. An important aspect of the siting process is that in an actual siting effort the participants develop or adopt their own criteria. The criteria presented in this report are suggestions that would only be used if accepted by a participant as reflecting his or her objectives. It is expected that additional criteria may also be identified by each participant.

The siting process and environmental criteria developed in this report are essentially draft or working versions at this time. They have benefited from critical review by a limited audience. Exposure to a wider audience, including the public and industry, would serve to improve the process and criteria and bring forth other issues or concerns not previously discussed.

It is recommended that the method be jointly exercised by the government and industry in an actual siting effort and that a handbook then be developed explaining the method and its use. The practical use of the method should be demonstrated and then reported. The actual application of the method would require generation of the additional criteria needed for siting but not developed in this study. These include socioeconomic, engineering, and similar criteria.

It became clear during this study that a mechanism for wider involvement in facility siting is essential to insure adequate consideration of diverse social, political, economic, and environmental concerns. Although a systematic siting process presupposes

that there are effective ways for the government and other interests to participate in site selection, no such mechanism is currently available. The Environmental Assessment and Review Process (EARP), granting of permits, and Northern land use planning do not establish the direct involvement of the government in siting. These are review processes concerned with a final proposal, not mechanisms for participating in the site selection process itself.

It is recommended that a study be made of what institutional mechanisms exist or would have to be created to permit the government to more effectively involve itself in the selection of sites for key facilities.

1 INTRODUCTION

1.1 Project Purpose

The Arctic is unique among areas of outer continental shelf (OCS) hydrocarbon development in its climate, the importance of geomorphic features such as permafrost and sea ice, the amount of wildlife habitat that it includes, and the lifestyle of its residents. Recognizing the special attributes of this region, Environment Canada (the Federal Activities Assessment Branch) and the Department of Indian and Northern Affairs (DIAND) solicited a study to describe a process for identifying environmentally acceptable areas or sites for OCS-related facilities in the Canadian North, particularly in the Beaufort Sea coastal area. The study will provide the government with a general siting method, supported by an enumeration and profile of environmental criteria that should be considered in locating hydrocarbon development-related facilities.

The project consists of two phases. The first is the development of a detailed method of identifying sites for energy facilities. This method is based on an assessment of US state-of-the-art facility siting and appropriate adaptations to the Canadian situation. Terms used in discussing the siting method are defined in the Glossary.

In largely undeveloped, uninhabited regions like the Canadian North, industrial development can have a significant impact. If it is extensive, development may overwhelm indigenous communities. Furthermore, in such ecologically sensitive environments, impacts tend to be more severe and continue over far longer time periods than in other regions. With these considerations in mind, project planners will need to outline choices that must be made in searching for a facility site. The method does not dictate final sites; rather, it insures that issues important in this region are addressed in depth and in a logical sequence, not ignored.

Because the approach includes setting forth appropriate criteria for siting, use of the method will engender fewer conflicts. Users will know what issues must be addressed, what areas cannot be disturbed, what areas require special design or operating restrictions, and what areas involve no special constraints on facility development.

The second phase of the project is to identify and characterize environmental qualities that would influence or be affected by development of OCS oil- and gas-related facilities, such as pipelines, support bases, and production facilities. These criteria are

used in judging whether areas should be considered acceptable, potentially restricted, or unacceptable for each type of petroleum-related facility.

The existing environmental data base and the additional data collection requirements to meet the needs of the facility siting model are also examined during the project.

1.2 Study Assumptions

The development of a complete, integrated siting methodology for major facilities is a complex undertaking. It would be unrealistic within the terms of reference of this study to create a comprehensive model siting process applicable to all prospective siting situations in the Canadian Arctic.

The principal assumption of this study is that the appropriate level of development of a siting process at this time is not a step-by-step handbook for addressing all possible decision points in a predetermined fashion. Rather it is a self-contained model siting process that identifies a philosophy of siting; the major phases of site selection; the role of decision makers; the key decisions; the principal techniques for making decisions; and the points where conflicts and differences between interest groups are identified. These conflicts are not necessarily resolved by the process. A handbook that considers in more detail the process and its relationship to specific facilities, different interest groups, the criteria, the data base, data management techniques and public policy would follow only after the basic methodology is judged to be acceptable.

A second basic assumption is that facilities to be sited by the process have been determined as necessary and consistent with Canadian policy. A siting methodology attempts to resolve where a facility is built and not whether it should be built. Although the process could be carried out with some decision makers participating "under protest," the decisions required to solve a siting problem do not usually permit a hostile participant who is unwilling to accept the premise that the facility must be located somewhere.

This assumption really deals with the scope of the siting study. For example, there may be a documented need for oil or gas consistent with Canadian energy policy. This need can be met from a variety of geologic provinces by a number of alternative facilities. Once the decision to exploit a certain resource area has been made, the next choice is the assemblage of facilities required to develop it. Only at this point does the siting process, as we discuss it, begin.

"Siting" in a broader or more global sense, which would determine on a national or Arctic-wide basis where facilities are located, is outside the scope of our method, although some of the issues and techniques discussed will be common to solving both problems.

A third assumption is that a reasonably comprehensive list of environmental criteria can be identified based on analogous situations in the US Arctic and readily available data for Canada. As explained in the description of the siting process, criteria are typically set by various interest groups to reflect their points of view. It is not possible for a consultant to represent all these points of view and, in fact, it would be inconsistent with the proposed process for the consultant to do so in an actual siting study. Criteria indicated in this report are those that we feel are most likely to be used in siting. However, additional or modified criteria may be proposed for specific studies by the participants.

1.3 The Geographic Areas and Facilities Considered

The regions considered in this study are onshore and offshore areas capable of supporting facilities for exploration, development, production, and transportation of oil and gas resources in the Canadian Arctic. Specifically, the Beaufort-Mackenzie Basin and the Sverdrup Basin are areas of current concern. These basins have been actively explored and development plans and facility sites have been proposed.

The Beaufort Sea area includes the coastal areas of the Yukon Territory and parts of the Northwest Territories in the vicinity of the Mackenzie River Delta. To 1990, resource development is oriented toward oil. The Sverdrup Basin in the northern part of the Canadian Arctic Islands, north of Melville and Lancaster Sounds, is nearly 600 miles long and 200 miles wide. Until recently, hydrocarbon discoveries were entirely gas, but oil was found in the Sverdrup Basin in 1981. The Arctic Pilot Project proposal for liquifying gas and transporting it from Melville Island to the south in icebreaking liquified natural gas (LNG) carriers is currently nearing a decision.

The facilities required for development of the resources in the regions considered in this study are the following:

- shorebases (support or service bases);
 - medium draft harbor,
 - deep draft harbor,

staff support bases/camps,

- onshore marine terminals;
 - for oil,
 - for LNG,
- offshore marine terminals;
 - for oil,
 - for LNG,
- Arctic Production Loading Atolls or Basins (APLA,s or APLB's);
- onshore pipelines, including pumping and compressor stations;
 - natural gas,
 - oil,
- offshore pipelines;
 - natural gas,
 - oil,
- partial production facilities;
- refineries;
- treatment facilities;
- barge-mounted LNG plants;
- barge-mounted methanol plants;
- drydocks;
- gravel mining operations/quarries;
- barite processing facilities;
- all-weather service roads;
- airstrips;
- shallow production islands; and
- deep production islands.

In some cases these facilities are linked or occur simultaneously.

This list of facilities was derived from development plans of Dome Petroleum Limited, Esso Resources Canada Limited, Gulf Canada Resources Inc. (Dome Petroleum Ltd. et al., 1981; Todd, 1981), and Panarctic (Gibbs, 1981).

Not all of these facilities have flexible siting requirements. A resource-oriented facility such as a production island or mining operation is sited to exploit the resource and only minor adjustments to its location are usually possible.

Although a siting process that is broad enough in scope to consider the above range of facilities and regions would be transferable to other facilities and geographic areas with some modifications, environmental criteria developed specifically for the Arctic would be unique to the region considered and to the range of facilities.

1.4 The Context for Facility Siting in the United States

The primary tools for involving the Federal government in siting major facilities in the United States are the National Environmental Policy Act of 1969 (NEPA) and the concomitant NEPA implementation guidelines set forth by the Council on Environmental Quality and individual government agencies and departments, such as Interior and Energy. NEPA requires the Federal government to assess the environmental impact of major Federal actions that significantly affect the environment and to consider alternatives to the proposed action, which may include alternate sites. Depending on the activity and the agency guidelines, an environmental assessment (EA), a more detailed environmental impact statement (EIS) or neither (for categorically excluded actions) is required. Also, depending on the action, different government agencies may be designated as the lead agency for the EA or EIS.

Other forces which may influence siting are State equivalents of NEPA, specific State energy facility siting acts (mostly for power generation facilities), approved State coastal zone management programs (which have federal consistency provisions), other siting programs and regulations (e.g. hazardous waste disposal facility siting acts) and specific regulations that include siting guidelines.

It would be inaccurate to say that NEPA, alone or in conjunction with other regulations or policies, always requires a site selection study in permitting and developing a major facility (the US Nuclear Regulatory Commission is one example of a government body that has explicit regulations regarding siting, which require the proponent of a nuclear power plant to conduct a site selection study). Although reasonable alternatives to major Federal actions must be considered they will often include alternate designs at the same site and not alternate sites. The primary question here is ownership of the site. If the Federal government does not own the site(s) and the proponent cannot reasonably be expected to move to another site that he does not own, then adequacy of environmental

protection measures rather than suitability of the site will usually be reviewed. Refusal to grant a permit may then result in seeking an alternate site.

Other more subtle forces in facility siting are public acceptance and licensability. Even when a siting study is not required, the proponents of a controversial facility (e.g. a refinery) may elect to do a site selection study before committing to pursuing a specific location. The site selection process will usually take place only if acceptance of the facility is likely to be improved. Some facilities will be controversial at any site. Most industrial facility locational decisions are based on some type of selection procedure; however, they may not balance economic and environment or involve external inputs.

An important issue in US facility siting is that decisions to approve or reject a proposed facility are usually made in the context of alternatives. These alternatives include alternate locations for the facility as well as alternate technologies and environmental impact mitigation strategies.

1.5 US State-of-the-Art Facility Siting

The term "state of the art" conjures up images of space age technology and computer-assisted techniques that perform a complex decision-making process. Our review of US siting indicates that the current level of development and prevalent practice is far less elegant. The spectrum of siting ranges from very simple intuitive methods to extremely complicated mathematical approaches. Although computer-based approaches and information systems are common for data management in siting studies, the ability to include decision-maker preferences accurately is much less advanced. The majority of computerized siting techniques require the decision maker to input his preferences in a predetermined and often indirect way (e.g. by supplying importance weights for issues). An assessment of the state of the art must, therefore, consider both data management and decision-making techniques.

A common denominator of many siting studies is the reliance on a phased site selection process. Typically this involves a regional screening (zone or area identification) phase, a candidate site (or potential site) selection phase, and a preferred site selection (or alternate site evaluation) phase. The process starts with a region of interest (study area) that is successively narrowed. Each phase is selective; that is, whatever approach is used must reduce the potential sites carried into the next phase. More specific criteria and more detailed analysis supported by new data are used as the

process progresses through to the selection of potential sites and the choice of a preferred site.

The rationale for a phased approach is that either data, analytical capability, money, or manpower are lacking to consider all relevant factors adequately for the entire study area. Each phase attempts to maximize the chances of finding a suitable site at the end of the process by considering the most relevant factors and available data. On this basis, siting processes may eliminate some possibly acceptable sites because better choices are perceived to exist. Other important considerations in a phased approach are (1) that unless the principal trade-offs are considered for the region of interest as a whole, the potential sites selected may not satisfy important objectives; and (2) new data collection or improved techniques for analyzing data can change the appropriate level for applying a criterion.

Not all siting methods use a phased approach. Some start with a slate of potential sites that have been nominated by the facility proponents or other knowledgeable and interested parties. An approach proposed by the US Nuclear Regulatory Commission (NRC) is based on selecting a minimum number of alternate sites that represent the diversity of the region of interest and pass a checklist of environmental, engineering and economic criteria (Dames & Moore, and Rogers, Golden & Halpern, 1980). The process used to identify the sites is not subject to review by NRC. Common reasons for not using a phased site selection approach are a small region of interest, a limited number of feasible sites, or a lack of reliable regional data.

Whether or not a phased approach is used, the most common techniques for executing a site selection process are exclusion (or inclusion) screening and weighted summation (rating and weighting) models. Exclusion screening is elimination of all potential sites or areas below a certain level regardless of the sites' or areas' performance versus other criteria. Inclusion screening is the reverse process: automatic consideration of sites above a certain level. For the weighted summation model useful distinctions are made within a criterion (see Figure 1). Say, for example, if wildlife productivity is the criterion, three distinctions may be made--low, medium or high productivity. Each level of distinction that is made within a criterion is assigned a "value" or rating (v), typically on a fixed but arbitrary scale (0-1, 1-10, etc.) common to all criteria being considered. A graph or table showing the values for all levels within the criterion is called its value function (Figure 1, step 1). The end points of the scale can be based either on the range of conditions that are known to occur in the study area or on a broader absolute range of

Step 1. Assign values (v) to criteria levels.

Value Function
for Criterion 1

level	v
A	1
B	2
C	3

Value Function
for Criterion 2

level	v
M	1
N	2
O	3

Step 2. Assign importance weights (w) to criteria.

Criterion 1 $w = 4$

Criterion 2 $w = 5$

Step 3. Multiply values by importance weights and combine.

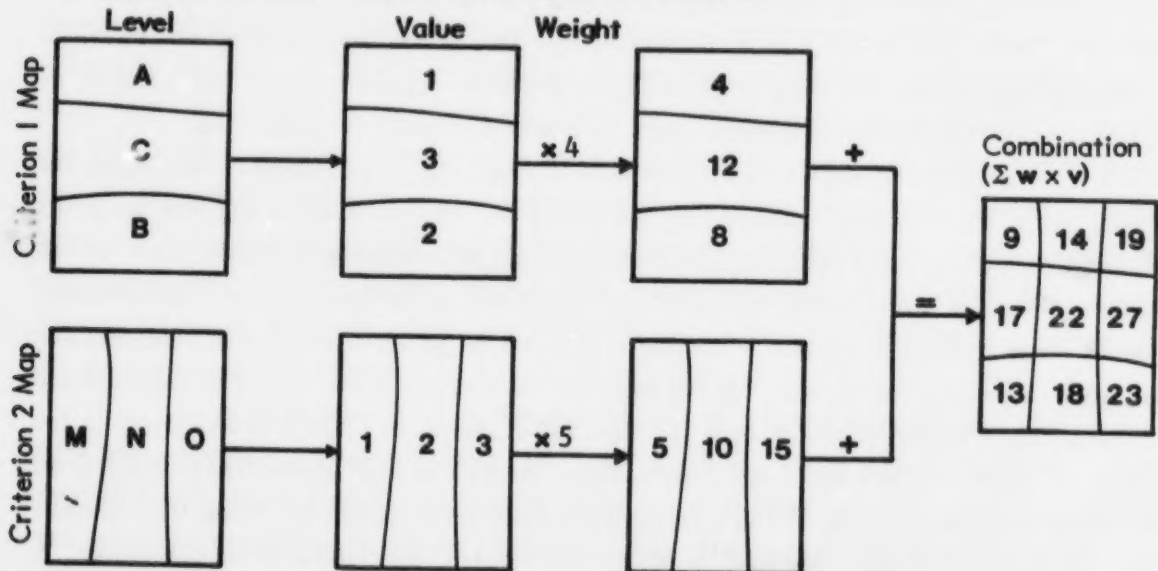


FIGURE 1 THE WEIGHTED SUMMATION TECHNIQUE

possible conditions. A weight (w) is subjectively assigned to each criterion to represent a person's judgement of its relative importance with regard to other criteria (Figure 1, step 2). For instance, a scale of 1 to 5 could be used to indicate a range from "little importance" to "extremely important". Suitability of a site or area is then calculated as the sum of the products of the weights and values for all criteria ($\sum w \times v$).

Exclusion screening is most often used to delete zones or areas within broader regions. Weighting of criteria is used both in identification of candidate areas and in comparison of sites. In that they are indicative of the stage of methodology development currently achieved by many industrial concerns and consultants for siting major facilities, these techniques could be said to represent the state of the art. Examples of their use are found in The North Channel Environmental Assessment (Ontario Hydro, 1978). Notwithstanding the frequency with which these approaches are used, there are more innovative and in many cases more appropriate techniques that have been applied to facility siting. Hobbs (1979) provides a review of many siting approaches in terms of theoretical validity, flexibility, results compared to other methods, and ease of use. Included in his review are tabular comparisons of techniques for determining weights and values. Of eight weighting techniques considered, only three--the Churchman-Ackoff, indifference tradeoff, and decision analysis methods--assigned valid weights. These were also characterized as among the most difficult to use.

Our understanding of more appropriate techniques vis-à-vis the state of the art requires recognition that the basis of siting is assessing preferences for trade-offs and not merely assigning numerical weights between competing alternatives (sites). This can be done in ways that avoid the difficulties with weights (discussed in detail in the next section) by reducing the siting problem to a reasonable number of direct choices.

Within the scope of this project it is not possible to discuss all siting techniques or even all those that might be relevant to the Canadian Arctic situation. However, it is important to recognize the principal features that distinguish between methods to understand why certain techniques have been proposed in the model siting process presented in this report. In the following discussion, the weighted summation and exclusion models are used to provide a basis of comparison.

1.5.1 Differences Between Siting Methodologies. Some of the principal differences between siting methodologies are:

- the extent to which they rely on exclusion criteria;

- the techniques used to consider trade-offs;
- the way in which decision makers' inputs are elicited and included;
- the procedure used to reach consensus when more than one decision maker is involved;
- the incorporation of uncertainty about effects and attitudes toward risk; and
- the evaluation of effects that vary over time.

The following paragraphs discuss each of the items in sequence.

In constructing a siting process, an unavoidable trade-off occurs between complexity and correctness. For example, consider a simple process based only on exclusion criteria. Using an exclusion approach, all potential sites that do not meet a certain minimum level of performance in a criterion are eliminated. Although the use of exclusion criteria is a simple concept to implement, it is not always a correct one. Theoretically, an exclusion approach should only be used when a certain level in one criterion makes a site unsuitable regardless of its level of performance in other criteria. Outstanding performance in other criteria cannot offset poor performance in an exclusion criterion. In reality this is often not the case. The critical factor with exclusion criteria is the level at which thresholds are set for making an exclusion determination. Thus, possible shortcomings of an exclusion approach are that it may on one hand eliminate all realistic sites and on the other hand not be selective enough to sufficiently reduce the area under consideration.

A weighted summation model is one approach to making trade-offs. This approach usually considers trade-offs indirectly. In fact, the basis of using weights is to provide a composite suitability map for potential sites that indicates which sites are preferred. This map avoids assessing preferences for specific trade-offs.

The weighted summation model seems conceptually uncomplicated, although this is not necessarily so if verification of all the assumptions is required. Even assuming that this model can be shown to be appropriate, misapplications of weighting are common, including those where the decision maker sets the weight for a criterion:

- 1) without understanding the meaning of weights;
- 2) without knowing its value function or the range of variation;
- 3) with its value function preset by others such as professionals in the pertinent discipline; and
- 4) whose value function represents only a ranking or ordinal scale.

The first case is obviously a problem. Weights have a specific meaning that is implemented mathematically. Without the decision maker understanding the weighting process it is unlikely that weights will express his or her preferences.

The second case is equivalent to assuming that valid weights can be set abstractly without knowing the units to which the weights are to be applied. This is also based on a misunderstanding of the meaning of importance weights. Use of weights for evaluating the relative importance of generic objectives is meaningless. Only when the weights can be related to a tangible, but not necessarily an economic, trade-off (e.g. additional mile of pipeline construction vs. volume of dredging) can they be interpreted to indicate preferences.

The third case is more subtle. Both weights and values are subjective. If the same person does not assign both the weights and the values, they will not necessarily represent the person's point of view. There are few cases where the value function is deterministic, except where there are only two levels such as presence/absence for the criterion. Although it is appropriate for professionals to advise the decision makers as to the implications of different value functions, the decision makers must evaluate or confirm their feelings about the relative importance of different levels within each criterion to make the method valid.

The weighted summation model is mathematical and the weights and values must have certain mathematical properties. Describing alternatives as low/medium/high sensitivity using 1 = low, 2 = medium, and 3 = high, where the numbers only represent a ranking, is an ordinal scale and is not a legitimate value function. To be meaningful, a value function must be based on an interval scale; that is, going from 1 to 2 is as important as going from 2 to 3. In this example, if medium were valued as closer to low than high, it might be ranked as 1.5 = medium.

All of the above errors have been made in siting studies. And, in fact, most studies using weights make at least one of them. This is not just an academic issue. The purpose of a decision model such as weighted summation is to assess preferences and the test of any siting technique is the accuracy with which it does this. Techniques or applications of techniques that are conceptually unsound can only reflect a decision maker's values by coincidence. Weights are best used to combine costs or similar factors. In such cases, the weights are based on known objective information. However, a valid approach using weights can be used if the process is structured to avoid the basic errors and verify unstated assumptions.

Decision makers' inputs are solicited and used in different ways, but most often some form of structured direct questioning is involved with interchanges between the group conducting the study and other interest groups. In some cases, inputs are also obtained from published information and records of opinion from other decisions. Decision-maker inputs are used to identify issues, select criteria, and establish preferences, including the choice of a site.

The most advanced techniques include an information and involvement program with publications and visual presentations and a strong format for asking the relevant questions and recording the responses. The Nominal Group technique is an example. This and other participation techniques are discussed in the Citizen Participation Handbook (Institute for Participatory Planning, 1978).

The types of questions asked and the types of responses needed are the major differences between decision-making techniques. Typically, those that ask for reasonable responses such as a preference between two alternatives are easier for decision makers to relate to than those with less direct questions.

Many current siting methods involve several decision makers with dissimilar points of view. Methods with weights use successive rounds of questions, comparison of weights to group averages, and interchange of each participant's rationale for weights to achieve a consensus. When the process has gone as far as it can toward consensus, average weights are used. Unfortunately, averaging of weights is not equivalent to averaging of viewpoints, and the results may not represent a compromise or the point of view of any one decision maker. An alternate approach is to use the results of each decision maker's weights independently and try to achieve agreement on sites that have been selected by several decision makers, albeit for different reasons.

The last two things on the list of principal differences between siting methods--incorporating risk and uncertainty and effects that vary over time--are not addressed specifically by the bulk of siting methods. Attitudes toward effects that have various probabilities of occurring or vary over time are implicitly considered in evaluating the suitability of various environmental situations for a facility site, if the decision maker is aware that they should be considered. In fact, most preferences in siting reflect some attitude toward uncertainty, otherwise sites prone to effects that can be mitigated would not be avoided. Time-dependent effects are usually considered by preferences for sites subject to short-term effects over those subject to long-term effects.

Rigorous analysis of attitudes toward risk and variations with time are only provided in decision analysis methods adapted for siting from other disciplines. The mathematics of decision analysis will be incomprehensible to most siting participants. Where attitude toward risk is a deciding factor and risks are quantifiable, the siting method would have to reduce the mathematical theory to a participant-oriented approach that is usable.

This overview of US siting practice is by no means exhaustive. The methods discussed are not all used in the proposed siting process, but the reasons they are not used are apparent from the overview. Specifically, we are not proposing a method based on weights for the reasons given. The process is based on consideration of the above and the philosophy given in the section Philosophy of the Siting Process.

The previous discussion looks at the systematic elements of siting. Historically and for political reasons, not all siting decisions follow a well-defined approach. The systems approach is balanced with experiences in the Alaskan Arctic. Although the historical approaches may not follow a model, they must, on a practical level, deal with who makes decisions, how trade-offs are made, and how a consensus is reached among conflicting users of the land. On these bases they can be compared to the model process.

1.6 Site Selection in Canada

Although considerably fewer site selection studies for major facilities have been performed in Canada than in the United States, there are an adequate number of Canadian studies to permit comparison. As in the United States, the majority of the studies are performed by utilities in siting electricity generation plants and transmission lines. However, siting-related studies for coastal energy facilities and pipelines are becoming more common. Canadian siting-related studies that we have reviewed include Ontario Hydro (1978), Kitimat Pipeline Ltd. (1976), Canadian Department of Development (1981), Arctic Pilot Project and TransCanada Pipelines (1981) and Fisheries and Environment Canada (undated). Only published, documented selection methodologies and siting examples were available in the limited time schedule of this study and no attempt was made to go beyond this information.

A report prepared for Environment Canada regarding power plant siting (Dames and Moore, 1979) was recognized by utilities as representative of the Canadian state of the art at the time of the study.

Recently, a report on the first phase of a study to prepare environmental criteria for siting thermal generating stations (MacLaren, 1981) summarized Canadian power plant site selection practices, based on responses to a questionnaire and the experience of the consultant. Aspects of the site selection process that were covered by the questionnaire included approaches to siting, techniques used, public participation, and the regulation of the siting process. The responses indicate the following:

- 1) both a phased site selection approach and a direct nomination approach, followed by detailed assessment of sites, are common, with the phased approach preferred;
- 2) numerical weighting for either identification of areas or evaluation of sites were used by about half the respondents. (It was unclear which methods, if any, the other half used);
- 3) public participation in siting studies in some way is fairly common and expected to increase; and
- 4) there was some uncertainty about whether a documented site selection study was required or voluntary and how the site selection process related to the Environmental Assessment and Review Process (EARP).

Specific studies for siting of oil and gas development support facilities in the Beaufort Sea area (Dome Petroleum Limited, 1979, Dome Petroleum Limited et al., 1981) have followed the practice of selecting sites acceptable to industry, primarily for engineering and economic reasons, and then assessing the environmental implications as required by EARP.

Except where the data are very simple or the region of interest is small, available siting methods depend on the state of the art in data management. If the technology is not in place to combine (overlay) maps to identify where specific data combinations occur, to prepare mapped and tabular information, and to perform logical and mathematical operations with spatial data, then methods for regional screening are limited to exclusion or inclusion screening or some type of hierarchical application of criteria. The Canada Land Data System (CLDS), through the Canada Geographic Information System (CGIS), includes this technology, so that it would be reasonable to assume that siting process options would not be constrained by data management capabilities. Not all data required for every study will be in the existing data base in the proper form, but digitizing new data is possible, assuming the appropriate data are available in another form. Demonstration siting studies using CGIS and computer-assisted studies by utilities have shown that the computer option is available if necessary.

Based on the brief review above, it would seem that Canadian site selection practices are comparable to their US counterparts. The most substantial difference is in the regulations that require the consideration of alternative sites. Although the greater number of US studies have explored more options and encountered more pitfalls, not all of the problems in siting have been resolved to the satisfaction of proponents of facilities, the interested public, or specialists in designing processes to consider the issues and trade-offs in locating a major facility.

1.7 A Context for Facility Siting in Canada

There currently is no political mechanism for direct involvement of various departments of the Canadian government (or the territorial governments or the public) in hydrocarbon-related facility siting in Northern Canada. Environment Canada and the Department of Fisheries and Oceans participate in primarily a reactive mode, that is, they exercise control through review and approval of plans and specifications or through permitting procedures. These approvals are specific to the development proposal and are made outside the context of whether preferred sites exist. Only indirectly, by rejection of plans for reasons that cannot be overcome without changing the site, is there an influence on siting.

DIAND has a legislative mandate to control the disposition of Canada lands above 60° north latitude. However, there is no specific legislation for land use planning. The justification for DIAND's involvement is related to the elements that are being planned, with its strongest mandate for planning being use of the physical resources of the land. DIAND is currently developing a strategy for implementing comprehensive land use planning in the Yukon and Northwest Territories (DPA Consulting Ltd., 1981).

Even with the proposed Northern land use planning systems and organizations in place, there is no direct role for DIAND in siting. However, siting is related to comprehensive land use planning in that both are concerned with appropriate uses of land and the suitability of areas for various types of development. The differences between planning and siting are largely in the specificity of the facility and the land area being considered. Under whatever planning system is developed and whichever organizational structure (of those suggested by DPA Consulting Limited) is adopted, the Northern land use planning process will provide a mechanism for involvement of the various government departments, territorial governments, and local interests. It will also develop a planning methodology. Because of the similarity of affected parties and issues in both siting and

planning, a siting method and a planning method will have many common points. Both will benefit from an organization that permits information to be distributed to and inputs received from a diverse group of participants in the processes.

2 THE SITING PROCESS

2.1 Actors in the Siting Process

Siting of a major facility can bring together a number of parties with different interests and potential roles in the process. In the simplest case, siting involves only one decision maker--the proponent or developer of the facility--who makes a decision based on the information available and the objectives and options for siting the facility. This approach is appropriate for siting noncontroversial facilities with fairly simple locational requirements.

As the complexity of the facility or the degree of controversy increase it may become necessary or appropriate to invite experts or affected parties to participate. Experts would be involved when the locational or facility requirements become more sophisticated, requiring specialists to analyze the implications of various siting options and advise the decision makers. Interest groups would be involved in an attempt to avoid conflicts that could delay the facility.

To distinguish various roles in the siting method presented in this report we have given names to the different actors. In the siting process described here, persons or groups asked to provide subjective inputs regarding their objectives and preferences for various trade-offs in siting the facility are termed participants. Persons or groups providing technical support in understanding the facility or in developing criteria are members of the siting team. They are not usually also participants and therefore do not make value judgements. Although each participant is a "decision maker" in the sense of making intermediate decisions such as objectives, criteria, and trade-offs, the term decision maker is reserved to the person or group ultimately choosing the site. This will typically be the proponents, although under certain circumstances the choice may rest with the federal or territorial government, specific governmental departments, or local interests. This will be the case when the proponent is indifferent between several options and other participants have strong feelings about which option is preferred. These other groups may also become the decision makers because of land use control, ownership, or claims at industry's preferred sites.

In addition to the above actors, the process will require a facilitator or project manager to organize and direct the site selection effort. The project manager keeps the process on schedule and on track by coordinating the various inputs and outputs for each

step and preparing schedules. In the same way that the siting team supports the participants, the project manager will normally have a support staff, which can include experts in siting, public or group participation, and data management. Because siting may result in conflict or an impasse leading to negotiations between participants, an arbiter or referee may also be required.

The various possible roles in the siting process--project manager, decision maker, participant, technical staff and arbiter--will not all necessarily be filled. In some cases an individual will take more than one role. For example, one participant may also be project manager, or the project manager may also function as arbiter of disputes. The complexity of the facility and the process and the capabilities of the participants will determine the need for support personnel. In simple cases only the participants will be involved. In other cases most of the technical needs will have been set by previous studies and there will not be the need for a large technical staff.

2.2 Philosophy of the Siting Process

It is important to understand the philosophy behind the proposed siting process. The following general principles are the basis of the process:

- There may be more than one participant (interest group).
- Objectives and siting criteria are identified by the participants, and each participant may have different objectives and criteria that will indicate how well potential sites meet his or her objectives.
- Each participant is assured that at least one candidate (potential) site selected from the region of interest represents his or her point of view.
- The process is structured so that the sequence of decision points and steps minimizes the data requirements and the number and complexity of trade-offs that have to be considered.
- There is provision for decisions obvious to all participants to be recognized and made directly.
- Trade-offs and conflicts between participants are resolved in selecting a preferred site, not in selecting candidate areas or candidate sites.
- The process makes decisions as explicit as possible by favouring a choice between two options over less direct approaches such as importance weights.
- Conflicts are resolved by negotiation and not by the mathematics of the process.

Each of the principles is apparent in the process.

The philosophy has important implications for use of the method. The most significant is that if there is only one decision maker the process is substantially reduced. The process is designed to benefit from different points of view since it is really an advocacy approach, in which sites are proposed and defended by constituencies whose points of view they embody. A single decision maker's point of view would ordinarily lead to considering a less diverse group of candidate sites.

This philosophy is different from that of siting processes that either involve only one decision-making group or that limit inputs so that the potential sites evaluated to find a preferred site may represent compromises.

The next most significant aspects of the philosophy are that decisions are made as explicit as possible and the process is structured to minimize the number of trade-offs. Because of difficulties in assigning valid, meaningful importance weights, the methods for making trade-offs between criteria are based on comparisons and ranking of specific situations. The rationale is that decision makers are better prepared to indicate a preference between two specific alternatives than to provide an abstract numerical weight for each criterion that would be used to indicate their preferences for all situations involving that criterion. A corollary to this is that the number of trade-offs that have to be assessed by each decision maker must be limited.

Other implications of the philosophy are discussed in the detailed explanation of the process.

2.3 The Relationship of the Proposed Process and the State of the Art

The siting process proposed in this report began with a review of US and Canadian site selection practices. The process is based partly on what has not worked (e.g. difficulties in using weighting), partly on well tried techniques that have been successful, and partly on examining innovative approaches for assessing trade-offs directly and incorporating the preferences of a diverse group of participants. In order to do this we looked at the ways in which people make spatial decisions and tried to include an understanding of them in our model.

The approach suggested has not yet been used as an integrated process, although most of the individual steps and techniques have been used successfully in siting. No single part of the process is beyond the current state of the art. The procedure for making trade-offs at the regional level is the most innovative aspect of the process, and

the decision analysis procedure with risk analysis, which has been used in siting, is the most complex.

Although the complete process has not been used precisely as written, our experience indicates that it is quite practicable. Specifically, the process used in the Maryland Major Facilities Study (Rogers, Golden & Halpern, 1977) is the closest practical application of a similar process in a major facility siting study. Lessons learned from that study and subsequent projects have been used to improve the process. An example from the Maryland study serves to illustrate this point.

The study was conducted for the Maryland Department of Natural Resources, Energy and Coastal Zone Administration, for major facility siting in the coastal zone. The major facilities considered included OCS oil- and gas-related facilities and other energy facilities such as power plants. Although the candidate areas were identified for all the facilities studied, the process was carried to the level of selecting sites only for power plants, that part of the study sponsored by the Maryland Power Plant Siting Program (MPPSP). The sites were selected as part of an acquisition program to develop a bank of backup sites should a utility have its primary site rejected in the approval process.

The primary actors in the process were MPPSP and a steering committee of State and county government officials, the affected utility, and public interest groups. The choice of candidate areas and sites was presented to each affected county. Local citizens were invited to comment at public hearings held in the vicinity of the candidate sites.

The principal lessons learned from the Maryland Major Facilities Study that were applied to this project are as follows:

1. It is difficult for all participants in a siting study to agree to exclude or include areas unless they are excluded by law or regulation. However, individual participants often have areas they feel strongly should be included or excluded. The Maryland Siting process originally called for using subjective thresholds of acceptability, analyzing their implications and adjusting the thresholds systematically. This approach was unsuccessful because of reluctance of the participants to come to a consensus on such decisions. This would have been more successful if diverse points of view were accounted for.
2. At least to the level of selecting potential sites, diverse points of view will usually exist and any consensus would be forced. A participant in the process will feel that

his or her point of view has been ignored if at least one of the candidate sites that is evaluated as a viable contender does not represent that point of view. In the Maryland study heavy emphasis was placed on the point of view of the watermen of Chesapeake Bay and the final sites reflected their inputs. The steering committee provided a broad range of interests including the utility, local governments, and interest groups, as well as State agencies and MPPSP. In addition, the utility whose service area included the region of interest commissioned a parallel study, which resulted in sites representing its point of view.

In retrospect, the process would have been more satisfactory if these points of view had been separated and one site selected clearly from each principal point of view, rather than four sites representing a mix of priorities.

3. The choice of the region of interest is an important siting decision. Defining a region of interest that in this case did not include the utility's service area in other states and did include areas that were subsequently ruled politically infeasible reduced the effectiveness of the study and misallocated the resources of the project.
4. Differences in facility options and outputs at a site are important considerations. The versatility of a site--in this case adaptability for a nuclear power plant or a coal-fired power plant with delivery by barge or by rail--was emphasized in selecting preferred sites. This can lead to a compromise site that is not the best for any options. Likewise, capacity of the facility is an important issue. Two of the preferred sites in the Maryland study have more recently been used in an alternate site comparison for a much smaller power plant. Differences in requirements could have led to selection of different sites originally.

All these items have influenced the development of the process presented herein.

2.4 General Steps in the Siting Process

The siting process proposed for the Canadian Arctic is complex enough that it is useful to look at the general sequence of steps before examining specific steps in more detail. These are five general steps in the siting process:

1. define the siting problem;
2. translate regional screening issues to spatial preferences;

3. select candidate areas;
4. select candidate sites from candidate areas; and
5. select preferred site(s).

Step 1 establishes the requisite framework for siting including characteristics and specifications of the facility, potential effects associated with its construction and operation, the region of interest, and the persons or organizations to be involved in site selection.

A phased approach, as described previously, is carried on in the remainder of the process. Steps 2 and 3 correspond to the zone or area identification phase, Step 4 to the potential site phase, and Step 5 to the alternative site evaluation phase. Steps 2 and 5 have the more complicated substeps and involve more innovative techniques. Within the area identification phase Steps 2 and 3 are separated because Step 2 results in an interim product for each participant. These products are combined in Step 3. In some cases, Steps 2 and 3 can be greatly abridged because of the strong preferences of individual participants or because of previous siting efforts. Step 5 either reaches a consensus or identifies negotiable or non-negotiable issues preventing it.

Although the proposed process generally conforms with common Canadian and US practices regarding a three-phased site selection study, there are important departures within the individual phases: numerical weighting is not used; decision points avoid a complicated regional screening when none is warranted; a specific goal is set for area identification; and the participants' attitudes toward risk are considered in evaluating potential sites when data on probability of effects exist.

The five steps present a broad outline that is useful to keep in mind when reviewing the detailed methodology. Each of the five steps can be analyzed independently if one recognizes the inputs and products from other steps.

2.5 The Process Flowchart

A flow chart for a siting process provides a description of the system of steps and decisions in applying the process. The flowchart considers possible alternative procedures that depend on the results of previous steps; for this reason, it is not always easy to follow. Because of the diversity of facilities and siting problems that must be considered, a generic model can complicate a simple siting problem and oversimplify a complex one. Not all procedures will necessarily be used in any one siting process.

The process flowchart for the siting method developed in this study is presented as a plate in the pocket at the end of this report. The flow chart is based on the following conventions:

1. The major steps of the flowchart are numbered 1 through 5. Steps within each numbered heading indicate how the major step is accomplished.
2. YES/NO decision points indicate which step follows based on the answer to a question or questions. Otherwise, the steps proceed sequentially.
3. Circled letters A and B indicate that the process provides input to a step later in the process that is identified by a similar circled letter.
4. Headings such as **"For each participant"** indicate that the subsequent steps are repeated as many times as appropriate. Indentations within these bold headings indicate loops that are repeated within other loops.
5. A series of steps enclosed by a box is repeated as indicated.

Relevant terms are defined in the glossary.

2.6 Specific Steps/Examples

The following sections explain the detailed steps in the siting process. Where the need for or products of a step are less apparent, an example is provided for that step.

2.6.1 Define the Siting Problem. Recognition of the nature of the problem is the beginning of its solution. The general problem to be solved by this process is finding acceptable sites for a specific energy facility or group of energy facilities within a defined study area. The purpose is to find preferred sites from possible sites. Where possible these sites are to be "optimal" in achieving objectives and avoiding conflicts. As well as the facility and the area to be considered, identifying the persons or groups that are to be involved in the site selection is part of defining the siting problem.

1a. Develop facility profile. A necessary component of the background data for siting is a common understanding of the facility on the part of the participants. The proponent of the facility will naturally have this information available and would normally present it as part of the regulatory process. Supplemental information is available from comparable facilities constructed elsewhere except for untried pilot projects.

A facility profile normally includes:

- a description of the facility discussing capacity, function, components and operation, construction, timing and ownership;
- requirements such as location, land, labor, water, transportation and power;
- additional concerns such as wastes, air quality, water quality, community benefits, safety, aesthetics, land use conflicts, revenues; and
- its relationship to other facilities.

Examples of facility profiles can be found in NERBC-RALI (1976) and Kramer et al. (1978). An excerpt from the latter is shown in Figure 2.

1b. Develop profile of potential effects. As the facility profile describes the facility, the profile of potential effects describes for the participant its interaction with the built and natural environment. Effects (impacts) are usually classified as general or activity-specific, local or regional, etc. and may also be classified as environmental quality, fish and wildlife, socioeconomic or historical and archaeological impacts.

A profile of potential effects includes:

- actions or sources,
- impacts,
- magnitude,
- term,
- location, and
- mitigation.

An example of an impact profile for petroleum-related development and production in the Alaskan Arctic is shown in Figure 3. Impact profiles will usually be facility-specific.

An important aspect of the profile of effects is the degree and effectiveness of impact mitigation. Although most major facilities in sensitive or critical environments are built with best available or practicable mitigation measures, the perception of an unmitigated effect is what is often considered in avoiding certain areas for siting. Some effects cannot be mitigated. Effects that can possibly be mitigated may not be considered by some persons in siting, and others to treat them as inevitable risks. A careful explanation of mitigation measures is essential in the profile to form an informed perspective.

Description

Onshore service bases are the staging areas for offshore petroleum operations. These industrial bases provide materials and services to sustain offshore activities. Materials are delivered to the base by barge, road, rail or plane and are stored until supply boats or helicopters transfer them offshore as needed.

MATERIALS REQUIRED FOR EACH EXPLORATORY WELL (tons)

MATERIAL	10,000 FT. WELL	14,000 FT. WELL
30" casing	18	18
20" casing	28	28
13 3/8" casing	82	82
9 5/8" casing	0	168
Bentonite	467	700
Cement	275	300
Barite	233	350
Misc. consumables	10	10
Fuel*	1,580	2,400
Drill water	2,500	3,750
TOTAL WEIGHT	5,193	7,811

*Including supply boat fuel

Source: NOAA

A service base used to be little more than a pier at the city dock. As oil companies began operating in more severe offshore environments, however, weather and timing became critical factors in the cost and safety of operations. Modern service base activities are structured to take advantage of good weather and to minimize the turnaround time for supply boats and helicopters. Service bases operate 24 hours a day during periods of peak activity and favorable weather.

All supplies and services are located at one comprehensive facility. Tubular goods like casing and drill strings are stacked and prestung for quick loading by crane when a supply boat docks. Water, fuel, drilling mud materials and cement are usually pumped aboard the waiting boat through pipelines. Some drilling mud materials and cementing materials are also transferred in crates or sacks.

TIMING

Service bases are the first facilities constructed onshore during OCS activity because they are essential to the earliest stages of offshore exploratory drilling. The search for service base sites may begin before a lease sale, and sites are usually chosen soon afterwards. In the northeastern Gulf of Alaska the Shell-Atlantic Richfield-Mobil consortium (SAM) purchased an unused cannery as a potential supply base site in Yakutat two years before the lease sale. Exxon and Dresser, the latter a major oil field service firm, secured sites in Seward soon after the sale. Texaco decided to use its sales distribution outlet in Seward as a base, and Atlantic Richfield (ARCO) arranged for storage area at the Seward Ferry Dock.

These examples of adaptation of existing facilities illustrate a tendency to improvise supply facilities at an early stage of exploration. The impulse toward numerous and scattered bases during exploration is strong as each operating company or group individually seeks a convenient support

Requirements

LOCATION

Service bases will normally be located as close as possible to offshore activities and coastal communities where they can use existing transportation and communication facilities and the local labor force. The maximum range from the rigs is 200 to 300 miles. For example, supply boats ran 213 miles from Seward to the semisubmersible exploratory rig, *Ocean Ranger*, when it was drilling off Cape Yakutat. Supply boats take approximately 12 to 14 hours to cover 200 miles. This is also close to the present maximum range for helicopters (Hutchison and Hogg, 1975), but new helicopter designs nearing production (Sikorsky S76) will extend the maximum range to about 300 miles.

HARBOR

A service base must have a sheltered harbor with a water depth of at least 18 feet at mean lower low water to accommodate modern supply boats. Harbor entrance depths should be at least 29 to 33 feet for a typical 17-foot draft supply boat. Channel depths should be at least 20 feet, the turning basin depth 19 feet and the berthing area depth 18 feet. The turning basins (diameter) are normally two to four times the boat length; hence, a turning basin for a 210-foot supply boat would be 420 to 840 feet.

Resupply barges (typically 250 to 300 feet long) docking at the service base require harbor depths of 16 feet or more and a turning basin of four to six times their length (1,000 to 1,800 feet).

SERVICE BASE LAND REQUIREMENTS

BERTHS	DOCK FRONTAGE	ACREAGE
1	200	4-12
2	400	13-20
3	600	19-29
4	800	26-37
5	1,000	32-46
6	1,200	38-54
7	1,400	44-63
8	1,600	51-71
9	1,800	57-80
10	2,000	63-88

ASSUMPTIONS

Initial acreage required for a one-berth base servicing:
 1 rig 3.50 - 7.50 acres
 2 rigs 5.75 - 10.25 acres
 2.5 rigs 6.75 - 11.50 acres
 Incremental requirements per berth at full capacity are 6.25 to 8.50 acres.

Source: Alaska Consultants, Inc.

LAND

The acreage required by a service base is related to the number of berths. Five acres per berth is a good rule of thumb, but a one-berth base may range from 5 to 12 acres. Exploratory bases in the Gulf of Alaska will range from 5 to 35 acres. During development, more materials are used and each berth generally requires 6 to 8 acres. A total of 25 to 70 acres, much of it used for storage, may be needed during

Additional Concerns

WASTES

Domestic wastes generated at a supply base require sewage treatment. The Yakutat supply base has a secondary treatment system that can handle up to 10,000 gallons of sewage per day. Actual sewage volumes for this base have been about 450 gallons per day. ARCO (1976) suggested the same capacity will be necessary for a service base in Lower Cook Inlet.

Federal regulations stipulate that solid wastes, such as paper and wood, be collected from offshore rigs and shipped to onshore facilities for disposal. Only waste material from the rigs and supply boats, such as oil sludges, used lubrication oils and oily bilge water, are separated and the oil wastes incinerated. The incinerator ash is used as landfill. Used drilling muds and drill cuttings are dumped overboard at the rig site in accordance with federal and state discharge permits. These materials are generally not contaminated with oil or toxic elements and thus are not harmful to the environment.

COMMUNITY BENEFITS

A properly designed and managed service base can offer economic advantages to communities. For example, ARCO and Shell signed a lease with Yak-Tat Kwaan, Inc. (Native village corporation) for operation of a 77-acre service base and industrial park near Yakutat. The lease obligates the oil companies to hire locally when possible and to keep the number of new families moving to Yakutat at a minimum. ARCO and Shell will be responsible for any necessary capital improvements on the property. Those improvements, including buildings, will become the property of Yak-Tat Kwaan when the three- to 20-year lease expires.

AIR QUALITY

Vapors and fumes from fuel storage tanks, transfer of fuel, combustion from machines and vehicles and accidental spills around a supply base may affect air quality. The extent of degradation depends on the size and location of the base and the volume of its operations (NERBC 1976). The Alaska Department of Environmental Conservation anticipates that dust will be the major air quality problem at Alaska service bases, but this can be minimized by watering, oiling or paving dirt roads.

Service base at Yakutat.



CONVERSION

Conversion requires foresight and planning on the part of a local community. For example, dock space at a supply base might be designed so it could later accommodate smaller boats. A supply base could be converted into a seafood processing plant, a marine transportation center, or an

FIGURE 2 AN EXAMPLE OF A FACILITY PROFILE FOR A SERVICE BASE (Kramer et al., 1978)

Table 3. Fish and Wildlife Impacts from Petroleum Development and Production

Source	Impacts	Magnitude ¹	Term ²	Location ³
Construction (material borrowing, foundations, facilities, pipelines, waste disposal, water supply, traffic, human presence, failure).	Loss/damage of aquatic, terrestrial, riparian, and coastal habitats.	**/**	**/**	**/**
	Mortality of fish populations	**	*	**/**
	Mortality of wildlife populations	**	*	**/**
	Blocks to fish passage	***	**/**	**/**
	Blocks to wildlife passage	***	**/**	**/**
Operations and maintenance (facilities, oil and gas wells, pipelines, waste disposal, water supply, traffic, human presence).	Fish entrapment	*	**/**	*
	Wildlife attraction or feeding	**	**/**	*
	Wildlife harassment	**/**	**/**	**
	Increased fish and wildlife harvest	**/**	**/**	***
	Loss/damage to habitats	**/**	**/**	**/**
Rehabilitation (removal of facilities, revegetation).	Mortality of fish populations	**	**	**/**
	Mortality of wildlife populations	**	**	**/**
	Blocks to fish passage	***	**/**	**/**
	Blocks to wildlife passage	***	**/**	**/**
	Wildlife attraction or feeding	**	**	*
	Wildlife harassment	**/**	**	**
	Increased fish and wildlife harvest	**	**	***
	Unknown—impacts depend on whether populations can recover following construction and operations impacts.	Unknown.	Unknown.	Unknown.

1. = minor; ** = moderate; *** = major.
2. = short; ** = intermediate; *** = long.
3. = onsite; ** = local; *** = regional.

1c. Are there various facility options that apply to different sites? One of the implicit assumptions of a site selection study is that facilities with similar requirements, capacities, and types of effects are to be built at any site selected. For purposes of siting, minor differences in site plans or design to accommodate site-specific conditions are not considered as different options. Only major differences in the facility would require adjustments to the process to make comparisons between possible sites with different options reasonable.

1d. Do facility options have different outputs (benefits)? If different facility options would be developed based on variations in sites, then the nature of the siting problem changes from comparing sites to comparing facility/site options. The options can only be made commensurable if their respective benefits are considered. For example, assume a shorebase is to be developed. For some sites, potential dredging or natural water depth make it possible to service deep draft vessels as well as shallow draft supply boats; at other sites shallow water depth and seabottom conditions make a deep draft harbor impractical. To equitably compare the sites, the difference in output (number and type of vessels accommodated) would have to be taken into account.

1e. Incorporate facility outputs as a siting criterion. If all siting options do not have the same capacity (e.g. in barrels of oil/day for a pipeline or an oil port), capacity automatically becomes a siting criterion. There are several options for considering it: (1) the difference in output can be treated as an individual criterion; (2) costs or quantified effects can be calculated per unit of output; (3) environmental effects can be adjusted to consider the same capacity at all sites. As an example of the last option, if coastal oil ports have different drafts at different sites, the greater number of vessel trips required to transport the same total quantity of oil would have to be considered to evaluate expected environmental consequences on an equal basis. Using the last option, preferred sites would have to be selected for each different capacity and these sites would then have to be compared.

1f. Identify participants (interest groups). A major element of a siting exercise is those who invited to participate. The siting process proposed herein relies on several diverse points of view to be most effective, although alternatively it could be used for a single decision maker to structure his siting decision. The issues considered and the outcome are usually a function of the number and mix of participants. On the other hand,

a very large group can make it impossible to manage the study or even to agree on procedures to conduct it. Only participants with a stake in the outcome or a mandate to be involved should be considered.

The basic group of participants for a siting study in the Beaufort Sea region, for example, could include the proponent, plus representatives of the Dene and the Inuit, local towns, DIAND, Environment Canada, the territorial governments, and a public interest group such as the Canadian Arctic Resources Committee or the Beaufort Sea Research Coalition. Depending on the facility and the region of interest, different actors may be involved. Because of succeeding steps, the number of direct participants must be controlled to limit the number of sites to be considered. This is accomplished by considering allied points of view and coalitions and organizations rather than individuals. The number above (approximately 9) would be both fairly typical and manageable.

The number of participants also depends on the developer. Unless the process is voluntarily expanded to include other participants, the developer may see the choice of sites to be defended in the Environmental Assessment and Review Process as solely within his or her purview.

Once a decision is made to include a certain person or group, guidelines for their participation must be developed. Questions to be answered include:

Where does each participant's involvement begin and end? Identification of concerns? Nomination of sites? Selection of a final site?

What is the time commitment required of the participants?

Will the study give representatives of groups a chance to consult their constituents before making key decisions?

Will participants who do not agree with the outcome have an opportunity to include a dissenting option in the study?

1g. Establish the region of interest considering the resource area the facility is to serve, existing facilities and regional environmental characteristics. The region of interest (study area) to be searched for preferred sites is a major siting decision since areas outside the limits studied are not considered as potential sites. (Also, data will not necessarily be collected outside the region.) The developer of the facility usually has the greatest control over selecting the region of interest, although it may be determined by the location of the resource or physical or political boundaries.

It is usually assumed that sites within the defined study area are not patently unfeasible from the standpoint of the developer. However, a large study area defined to have a reasonably contiguous boundary may include areas that are subsequently eliminated.

The region of interest should consider the environmental characteristics of the region. For example, if expanding the region would introduce a significantly different (less sensitive) ecological unit without undermining the feasibility of the project, the boundary would have been interpreted too narrowly.

The US Nuclear Regulatory Commission, in defining the region of interest for siting power plants (10 CFR 51), considers whether the region of interest may be made smaller or should be made larger depending on environmental diversity, institutional factors and cost considerations.

For example, the location of the resource area relative to ecodistricts would be one possible way of determining the region of interest based on a balance of cost considerations and environmental diversity. If the facility is a shorebase the travel time to the exploration or production area, a cost consideration, might be balanced against significant differences between ecodistricts, a measure of environmental diversity, and the current operating area of the oil company, an institutional factor, to determine a reasonable region of interest.

An example of a region of interest is the study area shown in Figure 1 of a report by Dome Petroleum Limited (1979) as the Beaufort Sea-Mackenzie Delta Land Use Planning Area. For shoreline-dependent facilities the region would only include sites with access to the shoreline.

The region of interest would indicate whether localized or more global issues would be considered in siting.

2.6.2 Translate Regional Screening Issues to Spatial Preferences. Siting involves the spatial depiction of issues. Only criteria that can be expressed geographically are useful in screening potential facility locations. At the zone or area identification phase, major trade-offs are examined to focus subsequent steps on areas most likely to contain preferred sites. The concept of probability or likelihood is important here since, particularly in an extensive, sparsely populated area, important data may be sketchy or unavailable.

Specifically, Step 2 is intended to have each participant identify a predetermined percent, say 5, of the region of interest that he prefers for siting the proposed facility. (The assumption is made that the region of interest is defined in Step 1 to preclude unacceptable outcomes such as inland ports.) This can be accomplished in various ways. The sequence of operations we propose for each participant is:

First, select preferred areas directly when there is only one rather clear objective;

Second, if this is not the case, use exclusion or inclusion criteria provided they can be justified;

Third, if the combination of all exclusion or inclusion criteria does not select preferred areas, then assess trade-offs, initially between levels within each criterion, then between pairs of criteria, and so forth. (Any exclusion or inclusion criteria are used in combination with these trade-offs.)

Worst case assumptions regarding the numbers of participants, criteria, levels within criteria and types of sites could create an unwieldy situation (as they would for any siting process). The process has been constructed to avoid this by: (1) restricting participants to choices involving their own issues; (2) limiting screening criteria to those that are appropriate at a regional scale; (3) only considering site types that actually occur and are not clearly unacceptable; and (4) attempting to determine the top percentage of the siting region rather than rank all possible combinations of criteria levels. These features of the process and our experience with siting studies would suggest that the worst case is unlikely.

The following sequence of steps is repeated for each participant.

2a. Identify, define and document objectives (issues). Issues are points of concern based on objectives. As the process is constructed, participants only specify their own objectives in this phase and are not responsible for presenting a balanced point of view. Balance is provided by various participants with differing objectives.

All objectives must be clearly identified and defined to be useful. They should be documented so that they can be modified if perspectives change.

One purpose of being specific about objectives early in the process is to provide a basis for subsequent identification of criteria and preferences. If the general priorities of participants are not first spelled out, then there is no way for them to structure their input to the process and no way to verify consistency of decisions.

2b. Is there only one objective? Depending of the number of major objectives, step 2 of the process may be much simplified. If there is only one objective there is no need to relate objectives to each other and, under certain circumstances, it may be appropriate to short circuit the sequence of steps and go directly to indicating spatial preferences.

2b1. Is the objective clear enough that preferred areas can be selected directly? An assumption is made in the process that some participants will have a simple agenda that makes their spatial preferences fairly obvious. If this is the case, the option of directly selecting that part of the study area most likely to be consistent with their objective is provided. This option only applies for a participant with one objective since multi-objective decisions are unlikely to be so direct.

Even with only one objective the participant can elect to follow steps 2c through 2w rather than choose areas directly.

2c. Establish a hierarchy of objectives. As an aid to assessing preferences, where related objectives have been identified, they should be organized in terms of subobjectives that contribute to a broader objective. Broad objectives include such things as minimize environmental impact and minimize development costs. Subobjectives include such things as minimize fish and wildlife impacts. The major objectives provide a basis for lower level, more specific objectives that contribute to them. Subobjectives that contribute to more than one broad objective can also be identified. The lowest level objectives are a guide to selecting criteria.

The following steps (2d through 2k) are performed for each objective:

2d. Identify criteria (attributes) that contribute to the objective. A criterion is a standard for comparing sites. It represents an extension of the hierarchy of objectives to specific characteristics of sites that contribute to realizing the objective. Whereas objectives are not typically mappable, criteria are, and combining data relevant to the criteria and preferences leads to a ranking of potential sites in terms of realizing objectives.

Steps 2e through 2k are repeated for each criterion.

2e. Investigate data availability, scale and range of variation, and correlation with other criteria. Data availability is the primary concern; if data are not available the criterion cannot be implemented. The size of data mapping units--whether large,

contiguous regions or small isolated sites--is useful in determining in which phase of the study the criterion should be considered. The expected range of variation within a criterion indicates its value in discriminating between sites. Although data that directly correspond to a criterion may not be available, correlation with some other mappable unit(s) in the data base may make it possible to consider it. Criteria that are highly correlated may be redundant.

2f. Is criterion appropriate for screening? Not all criteria are appropriate for examining the entire region of interest. Lack of comprehensive data coverage is one rationale for considering the criterion at other levels. Lack of significant variation across the study area is a reason for not considering it at all. A third case is where the basic data exist but have not been interpreted or compiled on a regional basis and a complicated analysis would have to be performed. An example of this would be trying to assemble information of land use and occupancy from many different sources. Another example would be trying to include an appropriate buffer distance from potential effects on caribou, where, based on terrain, different buffer distances are appropriate. If a criterion is not appropriate for screening, it should be reexamined in the candidate site and preferred site phases (at A and B respectively in the flowchart; Appendix III).

2g. Is exclusion or inclusion screening appropriate? Exclusion or inclusion screening require strong preferences on the part of the participant. They also correspond with the way many people make decisions. If there is ambivalence about the importance of a criterion, directly eliminating or including areas is inappropriate. Usually the most common exclusion areas are lands preempted by existing land use or regulated in some fashion by federal or territorial policy or law. The latter might include parks, reserves, and lands contested in native settlement claims. Common inclusion areas are existing sites, previously proposed sites, disturbed lands and, for some facilities, the vicinity of existing infrastructure. Inclusion areas are most likely to be suggested by the proponent.

An important consideration in this step is that the appropriate questions are asked to verify that inclusion or exclusion is appropriate; specifically, does a certain level in that criterion make a site suitable or unsuitable regardless of the levels of other criteria?

2h. Does suitability based on this criterion differ for areas not excluded (included)? Although potential sites (above/below) a certain level in a criterion may be (included/excluded), there may be more than two levels in that criterion and therefore

relative suitability between remaining levels would have to be considered. For instance, sites within 2 km of an Inuit village may be excluded but sites greater than 6 km may still be greatly preferred to those between 2 and 6 km. In other cases exclusion or inclusion may address all the interests the participant has in the criterion.

2i. Determine the appropriate levels for the criterion. The levels that express how well the criterion is met must now be determined based on the nature of the criterion and the available categories within the data.

For data that are normally continuous, such as proximity to important features, a continuous scale is used. For criteria where ranges of environmental conditions are classified into geographic units, each with a range of properties (e.g. ecosections) a discrete scale may be used. Where no natural scale is apparent, a constructed or descriptive scale may be used. An example of a constructed scale would be different degrees of harbor protection. Constructed scales are almost always discrete.

2j. Fill data needs or modify levels and assign areas to levels. The data needs step only takes place if the potential sites that occur cannot be assigned to levels based on the existing data. Modifying the levels to match the data or filling gaps in the data are the possible options. Data needs to be filled will not be overwhelming since data availability was considered in establishing the applicability of the criterion for regional screening.

2k. If greater than two levels, establish preference order for discrete levels or selected points on continuous scale. If there are only two levels (e.g. absent/present) for the criterion then the preference order is obvious. Likewise, with more than two levels the preference order is often, but not necessarily, obvious. For example, increasing water depth up to a required vessel draft may gradually improve the suitability of a site but greater water depths may provide no additional advantages and possibly disadvantages.

The purpose of this step is to compare levels within each criterion so that sites that differ only in that criterion can be properly ranked. Levels within the criterion may also be equivalent (i.e. the participant is indifferent between them).

Selected points on continuous scales are compared for the same reason: to determine whether suitability constantly increases or decreases; increases or decreases then levels off; or increases then decreases or vice versa.

An important consideration in establishing preferences, which is often overlooked, is whether the ranking of level within a criterion depends on levels in other criteria. The usual assumption that preferences are independent of the fixed level of

other criteria is usually verified by asking the participant to rank the levels with all other criteria at their worst level and again with them at their best level.

2l. Combine all exclusion (inclusion) areas. After exclusion or inclusion areas are identified for each criterion they are combined to determine their composite effect. In order for the process to be successful in finding a site each participant is constrained so that the entire study area cannot be either eliminated or included. Eliminating too much makes finding a site impossible or unlikely. Including too much makes the process non-selective. A maximum percentage that each participant can exclude (include) is established if constraints need to be made explicit. In most cases legitimate exclusion or inclusion criteria will not violate the constraints. If they do then the participant must reconsider and readjust the criteria.

2m. Do exclusion or inclusion criteria establish best n% of the siting region? This step is a check as to whether the exclusion or inclusion criteria alone meet the goal of regional screening. This happens if either the appropriate percentage has been included or excluded or all criteria are either exclusionary or inclusion-based. In the latter case particularly the target percent may not be achieved precisely. Whatever area has been included or has not been included is as selective as the regional screening can be for that individual and any random choice of n% within the remaining eligible area is equally acceptable.

A value judgement is required regarding how precisely the target must be achieved since the additional effort to reach it as closely as possible may be unjustified for regional screening.

2n. Group continuous criteria levels into classes. The next nine steps (from 2n to 2v) are aimed at identifying the trade-offs that need to be made and assessing preferences only as necessary to rank potential site types. Since the overall goal of Step 2 is a specific percentage reduction in the area carried into Step 3, identifying the important trade-offs requires knowledge of the frequency (percent) with which various types of sites occur. To accomplish this for a criterion with a continuous scale the range of values must be grouped into classes.

The class limits are based on the significance of incremental differences within the criterion and on the cumulative frequency distribution of areas for the criterion. More classes are used in the more suitable part of its range for siting the facility since these areas are more likely to be selected.

2o. Compile statistics on combinations of levels and their frequency of occurrence.

Once all criteria are classified into discrete levels, there are a limited number of possible combinations of criteria levels, only some of which will actually occur. This is because phenomena tend to cluster based on relationships between them (i.e. substrate is related to vegetation is related to habitat and so forth). In order to know which sites will be considered in the top $n\%$, the frequency of occurrence of each combination is important information since any combination with greater than $n\%$ of the siting region superior to it will not be considered further. In Appendix II, Figure 2a shows a sample frequency distribution for a region with three criteria, each having three possible levels (A, B and C).

2p. For each combination of criteria levels determine % of the siting region (1) that is inferior; (2) that is superior; and (3) where relative favorability is unknown without more information on preferences. Based on the frequency of occurrence established in the previous step and the preferences within individual criteria from Step 2.6 - 2.12 it is possible to establish the three percentages above for each combination. (Note: In the worked example of Appendix II, A for each criterion, represents the most suitable condition for siting the facility, B the next most suitable, C the least suitable.) The principle that applies is that one site is superior to another if it is equivalent or better in all criteria and better in at least one criterion. Other preferences cannot be established without considering trade-offs between criteria. An example of the results of this step are shown in Appendix II, Figure 2b.

2q. Can the best $n\%$ of the siting region be identified by preferences within individual criteria? If obviously superior sites are present in sufficient numbers (area) then further choices need not be made. For the example of Appendix II, if $n = 1\%$ then trade-offs need not be considered further and the process goes directly to the last step with combination 1. But if $n = 5\%$, trade-offs must be considered using the block of steps from 2r to 2v. Because of the subjective judgements in establishing the target percentage, a certain tolerance should be permitted in achieving it precisely to avoid complicating the process.

2r. Identify which trade-offs involving two or more criteria are most efficient in establishing the best $n\%$ of the siting region. If the process reaches this point, trade-offs between criteria will have to be considered, but only those trade-offs involving combinations of criteria levels that are possibly within the top $n\%$. In the example of

Appendix II Figure 2, if $n = 5\%$ then the last four site types should be eliminated because more than $n\%$ of the region is superior. The most efficient trade-offs involve criteria 2 and 3 in the example because three of the five remaining combinations together involving 21% of the region differ only in that pair of criteria. Efficiency as used here means the relative usefulness of a pair of criteria in deciding preferences among combinations in order to determine the best $n\%$.

For each trade-off identified, steps 2s-2v are executed until the answer to question 2v is yes.

2s. Establish for which criterion the participant would prefer to go from best to worst level. Normally this step is an aid to establishing preferences for trade-offs between two criteria being considered. If both criteria are binary (e.g. habitat present/habitat absent) this information completely ranks all combinations. Otherwise the next step is necessary.

2t. Determine order of preference (or indifference) between combinations of criteria levels. In order to rank them, preferences must be established between combinations of levels that are being compared; for instance, A in criterion 2 and B in criterion 3 vs. B in criterion 2 and A in criterion 3. Criterion 1 is at level A in both cases. In Appendix II Figure 2c a matrix from comparing criterion 2 with criterion 3 is established. Cross-hatched combinations do not occur. The heavy border indicates the relevant combinations to be ranked. The entries in the matrix are filled in by the participant to indicate his first, second, third choice, etc. in order of decreasing suitability for locating the facility. An example of a similar ranking of combinations is found in the transmission corridor band selection study for the North Channel area of Ontario (Ontario Hydro, 1978). As in Step 2k, it is important to verify whether preferences depend on the levels of other criteria.

2u. For each combination of criteria levels determine % of the siting region (1) that is inferior; (2) that is superior; (3) that is equivalent; and (4) where relative favourability is unknown without more information on preferences. This is a reiteration of Step 2p incorporating the new information on preferences collected in the preceding step. As an example based on the preferences in Appendix II Figure 2c, the percentages from part b of the figure can be revised as shown in part d.

2v. Can the best n% of the siting region be identified? In the worked example, with its target of $n = 5\%$, either the top 3% (combinations 1, 2 and 3) or the top 13% (combinations 1-3 and 5) could be identified. In this case, the data and criteria and preferences can be no more selective.

2w. Map the best n% of the study area. After exclusion or inclusion and ranking of combinations has progressed as far as it can, the results of previous steps are graphically displayed for future use in the process. If the process does not select the best n% precisely, then the possible percentages bracketing the target percentage that could be used should both be identified and mapped (e.g. 3 and 13% in the example).

2.6.3 Select Candidate Areas. Step 3 consists of selecting candidate areas from among the best n%'s of the region of interest as chosen by the participants in Step 2. The selection of candidate areas is subject to the four rules shown in the flow diagram. These rules are constructed to keep all participants involved in the process as well as to maximize the chances of finding sites preferable to two or more interests.

Only the second rule is necessarily applied; the others depend on the zones identified previously. The first rule is only applied if a participant opts to have mandatory inclusion areas. The third rule will only be applied if preferred areas overlap. The fourth rule takes care of situations where there are significantly different areas that meet the other three rules.

As with Step 2 there is usually a limit on the area that should be carried to the next step. The maximum area should be an agreed-to percentage (n%) of the region of interest, which is what would happen if everyone's areas from Step 2 coincided. Without putting a maximum on the area to be included, the entire region of interest might have to be examined in selecting candidate sites. This would defeat the purposes of regional screening.

An assumption of this process is that potential sites within the top n% of the region for each participant, while not necessarily optimal, are acceptable and preferred to many potential alternatives. The second rule allows for the most preferred sites for each participant to be selected when they are known.

2.6.4 Select Candidate Sites From Candidate Areas. Candidate areas are typically much larger than the area actually required for the facility. It is necessary, therefore, to focus on potential or candidate sites that can be reasonably considered for development

within candidate areas. Candidate sites are selected to represent the points of view of the participants so that within the next step at least one site can be identified with each participant in the siting process. There will typically be: (1) one site for each participant; plus (2) an additional site for each overlap between participant's candidate areas; plus (3) several additional sites to account for uncertainty and diversity of the region of interest.

4a. Define and document additional criteria and reexamine criteria used to identify candidate areas. Because the area has been reduced significantly, different criteria become practicable. They can be fine tuning or variations of existing criteria or completely new criteria. Criteria in this phase are still based for the most part on available data, although of a more specific nature. They may be based on maps, remote sensing, and from knowledge of the participants. The general term for this information is reconnaissance data.

4b. Collect additional data about candidate areas from published reports, flyovers, and site visits as appropriate. Under the assumptions of a phased siting approach, new data will be required to support Step 4. In the Arctic, flyovers would probably be the only reasonable way to gather new reconnaissance data. Exceptions to this would be areas near existing settlements where visits to the sites and contacts with residents would provide new data. The level of data gathering depends on the number and dispersion of candidate areas.

4c. Verify regional screening data and revise selection of candidate areas if appropriate. New data or closer examination may reveal that areas included on the basis of regionally available data and regional criteria would not have been included in candidate areas had actual conditions been known. Where this is the case and there are abundant candidate areas, the areas that violate the screening criteria may be eliminated. Otherwise, parts of Step 3 may have to be retraced.

4d. Select candidate sites by professional judgement and the consensus of the participants, with each participant deciding candidate sites that best represent his point of view. In many cases, candidate areas will be large and fairly homogeneous so that selecting sites will involve largely arbitrary value judgements. In such a situation one participant may have preferences for only certain parts of a second participant's candidate areas and the second participant may be indifferent to which of the potential sites within the area are selected. Professionals who deal with siting and engineering

facilities can also use their experience to winnow out somewhat less suitable potential sites. A combination of participants reacting to others' candidate areas, expert input, and attempting to lay out workable facility sites within candidate areas are used to identify potential sites to carry into Step 5. Because of limited siting study resources, the number of sites is subject to the consensus of the participants, although each is guaranteed one potential site acceptable to him.

Based on similarities in their candidate site(s), two participants may agree that only one of their sites needs to be considered. In other cases additional sites may be added because participants cannot agree on which to pursue. The consensus required among participants in this step is weak. Essentially they are deciding what level of effort is appropriate to perform Step 5.

2.6.5 Select Preferred Site(s). The purpose of this step is to achieve the overall goal of the site selection study--selecting preferred sites. However, preceding steps have been necessary to set the stage for it. The goal may be more than one site if a prime or preferred site and an alternate or alternates are desired.

Steps 5a and 5b are performed for each participant.

5a. Develop site-specific criteria including criteria retained from previous steps.

All important considerations that have previously been suggested but have not been incorporated because of their complexity or scarcity of data should now be evaluated for application as site-specific criteria. The number of sites is now manageable and new data collection on a limited basis would be feasible. Criteria that are not considered at this step and have not been previously considered will not influence site selection but may be part of the EARP.

5b. Relate criteria to previously established hierarchy of objectives. To verify that the site-specific criteria are consistent with the objectives and criteria used previously, they should be compared to the basic hierarchy of objectives established at step 2c.

5c. Conduct an interchange among participants to establish a comprehensive list of objectives and a constituency for each objective. Until this point in the process, participants have not necessarily shared objectives or criteria or reacted with the same preferences to environmental situations and trade-offs. An opportunity is now provided for them to exchange their points of view formally and to decide to which criteria they

will react in evaluating sites. The comprehensive list is used to establish data needs and to identify likely points of agreement.

5d. Collect new data for each candidate site as required to support site-specific criteria. The need for this step is obvious. A key question will be the extent of the effort to acquire the data and whether it is justified.

5e. Evaluate potential effects at each site using more detailed studies. Only when candidate sites that been thoroughly screened is it usually worthwhile to consider potential effects in more detail than in the general profile of effects developed as part of Step 1a. Again, this is a study-specific choice based on the significance of the issue and the level of effort required to explore it further.

Step 5f and either Step 5g or Steps 5h and 5i are performed for each participant.

5f. Are there any probable risks that are quantifiable? Attitudes toward risk and the success of mitigation are implicit considerations in choices regarding trade-offs. For some of the facilities being considered for the Canadian Arctic, risks of such events as oil tanker or LNG carrier collisions and groundings, pipeline ruptures, oil spills, and LNG explosions are important issues. The question is whether they are siting issues.

In order to be considered explicitly in siting, the risks must be of major importance and quantifiable, and either the risks or their effects must differ significantly based on the location of the facility within the region of interest. Only if these three conditions exist can this question be answered affirmatively.

5g. Decision Analysis Procedure. If the answer to question 5f is yes, a systematic mathematical technique for evaluating the participant's attitudes toward risk and preferences for various consequences is necessary. This technique--known as decision analysis--is too complicated to be explained adequately within this report. The major steps are listed under 5g in the flow diagram.

There are many references in the literature of decision science and economics that explain decision analysis thoroughly. Keeney (1980) presents a discussion specific to energy facility siting with examples.

Form the standpoint of participants, the important aspects of decision analysis are how well the technical aspects and the decision-making aspects are separated and

presented. This technique requires technical support by experts in both the decision analysis and the evaluation of risk.

5h. Is previous information or preferences sufficient to determine preferred site(s)?

In most cases the more complicated risk evaluation approach is not appropriate for the facility and a procedure similar to that used to assess preferences in Step 2 would have to be used. In the simplest case only more precise evaluations of the same trade-offs would be involved and preferences established in Step 2 would be adequate to determine preferred sites. The usual case is that the site that represents the participant's point of view will be his preferred site and other sites will be ranked based on how closely they match the preferred site. Also there will usually be fewer levels to consider for each criterion because previous screening will have eliminated less satisfactory levels.

5i. Collect additional information on trade-offs as necessary and assess preferences. Where previous responses to questions and opinions have not established preferences for each participant, additional trade-offs will have to be subjectively evaluated. Procedures as in Step 2 would be a possible option. In this case, specific sites are being evaluated and the trade-offs can be made more directly than for generalized site conditions.

5j. Determine preferred site, alternate site and ranking of other sites. Using preferences based on specific trade-offs between criteria and an overall view of the sites each participant determines his best option plus a backup site. Other sites are also ranked to help identify the degree of disagreement between participants. An important part of this step is that each participant evaluates all candidate sites to determine those that are unacceptable to him. Reasons for the site being unacceptable are clarified and carefully documented so that his problems with the site are explicit.

5k. Determine the sites that are acceptable to all participants. By accumulating the results of steps 5g or 5h-5j for all participants it becomes apparent which sites are acceptable to all and unacceptable to at least one of the participants.

5l. Is there at least one site acceptable to all participants? If there is no site acceptable to all participants then the choice of a site must be resolved by a negotiation procedure where the merits of objections are scrutinized and evaluated by an arbiter. One possible approach is to subject the site to the EARP where one site would be

acceptable to all but one participant. Where two sites are contested but one of them will likely be chosen, subjecting both to the review process would be useful.

If a least one site is acceptable but not preferred by all, there are additional possibilities, described below, to avoid negotiation or simplify the negotiation process.

5m. Is the site preferred by several participants and ranked high by other participants? Should this condition occur, it is equivalent to a consensus that the site is a good choice for the facility. Only other sites that pass this test are possibly preferable.

5n. Identify types of conflicts that lead to differences in preferences. If sites are acceptable to all participants but the same sites are not preferred, then it becomes important to identify which specific criteria, characteristics of the sites, or differences in viewpoints of the participants are causing the conflict. Depending on whether polarity of opinions or lack of a clearly superior site is the reason for the disparity, different approaches are possible.

5o. Can conflicts be resolved by changes in the facility or mitigation techniques? If the differences between participants are based on characteristics of the site that are amenable to mitigation or change then they may reconsider their preferences, subject to stipulations about the construction or operation of the facility. Otherwise the process has gone as far as it can without direct negotiation among participants.

5p. Negotiate to determine preferred sites. The negotiation process considers the facts and politics of the siting process. Depending on the participants there will be different financial, political, and resource commitments at stake in the decision. A negotiation process recognizes the realities of siting. Given that not all participants will have their preferred site selected and some may not even find all sites being considered acceptable, the arbitration technique used will be based on the relevant facts of the siting problem.

Specifically, each participant will know which option he prefers; he will know others aligned with his point of view, and he will recognize the best and worst outcomes of the siting process.

5q. Are more studies required to resolve dilemma? The outcome of the negotiation procedure could conceivably point to information that would satisfactorily resolve the remaining disagreement between participants. This information may not have been

collected previously because of the effort involved. However, with the perspective of being a single unresolved issue it may now be worthwhile to collect it.

5r. Collect supplementary information. Any data being collected this late in the siting process is study-specific and issue-specific and involves a new research or data analysis effort.

5s. Designate preferred site and alternative site(s) as backup. The process ends with this step. Alternate sites are usually selected for future planning and for a second choice should the prime site become untenable after the environmental assessment or site engineering studies.

2.7 Application of the Process

As presented in the previous section and the flow diagram (see Appendix III), the siting process seems somewhat complicated and perhaps too rigid, from the viewpoint of the participant. There are 55 numbered steps of which some, such as Steps 3 and 5g, have several parts. Thirty-one of the steps are repeated for each participant. Of these, some are repeated for each criterion, for each combination of levels, for each site or for each site acceptable to all participants. If this effort were required to be performed entirely by the participants the complexity of the process alone might deter its use. However, in this practice this situation is improved because either not all steps are performed, some steps are trivial, or steps are performed by others. For example, of the five major steps, Steps 1, 3 and 4 do not heavily involve the participants: only 1g, 4a and 4d require the efforts of the participants, and 1g and 4d only call for the participants to assent to or sanction the results of a group effort. For what seems to be the most complicated block of steps--2n through 2v--only Steps 2s and 2t require input from the participants. The other steps are performed by the project manager and his supporting staff and are not apparent to the participants. Likewise, other steps that deal with data gathering, data analysis or mapping (such as 2e, 2f and 2w) are performed by supporting personnel, and only the results are visible.

Other possibilities for simplifying the siting process depend on circumstances. It is obviously simpler to go directly from Step 2b1 or Step 2m to Step 2w, but whether it is possible or appropriate will depend on the nature of the siting problem and the participants. In effect Steps 2, 3 and 4 are a procedure for nominating sites to be evaluated. The calculated constraints placed upon the nominators and the data and

resources made available to them during their selection are what distinguish the proposed method from others. Obviously a participant could choose sites directly, either at random or based on knowledge of the region, but this would not be equivalent to Steps 2, 3 and 4. Objectives, criteria, exclusion areas and trade-offs, which are now considered for the second or third time in Step 5, would have to be developed from the beginning. New data would not be available to help select potential sites. The chances of finding consensus sites, which are increased in Step 3, would be reduced to coincidence. Bypassing these steps would shorten the process, but only by weakening it.

The application of the process can be simplified, without diluting it, by assigning steps to the appropriate actors in the process, who were described previously. Each actor is only aware of those steps that provide him information and only responsible for steps that require his inputs. Only the project manager must be familiar with all of the steps and responsible for coordinating them.

2.8 Variants of the Process

Although it is necessary to be somewhat inflexible in writing a stepwise description of a siting process, in practice the success or failure of a process depends on its ability to be modified for specific situations and on the skill of the persons directing the siting study in improvising appropriate responses to problems. For example, one problem that often occurs in siting is that certain interests, which have not participated previously, become concerned when it becomes apparent that a site they oppose might be chosen. The flexibility of the method can be seen in how it deals with this situation: possibly by clearly demonstrating that the choice was reasonable, or possibly by allowing the information provided by "intervenors" to be used in evaluating potential sites.

The primary variations of the process that are discussed in this section are those related to differences in facilities and the joint siting of assemblages or linkages of facilities.

2.8.1 Modifications for Specific Facilities. No generic siting process can address all the variations introduced by specific situations; however, some comments on the complications introduced by different types of facilities are needed to indicate how the methodology would be modified.

Four different situations exist: (1) a facility on a contiguous, compact site with most of its effects occurring on-site; (2) a similar facility with most of its effects occurring off-site; (3) a linear facility or corridor connecting specific endpoints with

effects occurring along its entire length; and (4) intermediate situations and combinations. The model siting process is most directly applicable to the first two situations. Facilities such as a pipeline that are in the third category have additional requirements that complicate siting. As proposed in the siting process, identifying the best n% of the region for a pipeline corridor would only be satisfactory if coincidentally this area connected the planned origin and destination of the pipeline. Otherwise some type of more complete ranking and way of evaluating competing corridors would be necessary.

Siting of a facility that would require a corridor connecting specific endpoints might be accomplished as follows:

1. Identify and map endpoints, including possible alternate endpoints and any intermediate points, such as pumping stations or compressor stations, that must be connected to the corridor.
2. Rank combinations of criteria levels and group them by rank or percentage of the siting region that is superior. Show this information on a map as rank numbers or percentages. (Some device such as grey level shading--lighter is better--helps in visualizing favourable corridors).
3. Lay out corridors as broad bands through the more favourable areas. The bands will be wider where there are no strong determining factors and narrower where there are many constraints.
4. Divide each corridor into segments to allow for places where there are several competing bands for a participant.
5. For each participant, compare bands to identify competing alignments for various segments.
6. Evaluate segment alternatives.
7. Connect preferred segments, considering minimizing the length or cost of the facility. (Length is considered throughout the process by each participant in selecting bands to minimize cost or impact).

These steps fit within the general framework of the siting process as proposed. The ways that participants provide inputs regarding objectives, criteria and trade-offs would be as in the basic model, but additional effort or different emphasis on certain steps would be needed.

Other variations would commonly be applied in considering the marine, road, or air transportation requirements of a facility as they affect siting. For example,

facilities that require marine access for oil transshipment to distant processing plants would have to consider the risks and potential effects of exposing new marine areas to the risk of an oil spill. This analysis would need to be based only on the effects due to links of the marine transportation route that were not common to all facility locations under consideration.

2.8.2 Linkages Between Facilities. The types of facilities listed earlier in this report are for the most part closely linked; that is, a site chosen for any one of them has implications for the location of others. Likewise, existing facility sites influence the siting of facilities yet to be constructed.

In order to consider linkages between facilities in siting, the most common approach is to carry on independent siting efforts up to some point in the process and then to compare results and let the relationship between facilities influence subsequent steps. Usually this "checkpoint" is at Step 3, the selection of candidate areas. For example, marine terminal candidate areas and general pipeline corridor bands may be compared to indicate both potential sites and potential corridors for the next siting phase. Similar comparisons would be effective for other linked facilities. Specific pairing of facilities (e.g. pipeline/port combinations) is often carried into Step 5, the site evaluation phase.

In siting an assemblage of facilities, the group of facilities needed and their influences on each other need to be considered from the start of the process for the first facility. This is only possible if the developers have planned or projected development and facility needs for some time into the future, say 10 years. In the siting process there is an important distinction between facilities that can occur simultaneously and facilities that are connected by road, pipeline or water. In the first case a facility complex can be considered as a single unit for which criteria can be developed and sites selected. In the second case, criteria have to be developed and candidate areas chosen independently for the facilities on compact sites and the linear facilities that connect them. The relative importance of getting the best site for a terminal and a less satisfactory pipeline corridor, and vice versa, must be considered.

Another important consideration regarding siting an assemblage of facilities is the status of existing facilities. It would be unrealistic, for instance, to let a temporary support base sited as a matter of convenience near an existing settlement determine the future location of all development facilities. On the other hand, a major refinery/terminal/liquification facility would necessarily and correctly exert a strong

influence on siting other facilities. The questions here are the duration of the existing facility, its scale relative to development yet to come, and the expected changes in environmental quality that would result from abandoning previous locations. These questions would be answered in the negotiation part of the siting process.

3 ENVIRONMENTAL CRITERIA

3.1 Selection of Environmental Criteria

Siting studies are generally structured to proceed through several sequential phases. In the initial phase, a large area is screened to identify subareas that may be suitable for facility development. These, in turn, can be evaluated in greater detail during subsequent phases of the investigation. Criteria constitute the means by which a region's sensitivity to our suitability for a specific development project can be measured. In site selection studies, criteria are generally found to be useful for regional screening, selection of potential sites, and site evaluation. Regional screening criteria are usually employed in the initial phase to eliminate from further consideration lands that are particularly sensitive to development. Where areas cannot clearly be excluded, the screening criteria provide guidelines as to areas that are likely to contain better sites. The regional criteria should: 1) be composed of units that can be mapped on a regional scale from available sources of information; 2) exhibit significant variation; and 3) be important to siting the facility.

Once the region has been reduced to specific sites or areas, it then becomes appropriate to use more detailed criteria. These criteria do not necessarily need to be in a mappable form, since specific locations are now being evaluated. Although a field reconnaissance may provide site-specific information of particular value, evaluations should concentrate on existing reports, documents, and personal contacts. Since the size of the area has been reduced at this stage of the study, it is also possible to consider those environmental factors that exhibit subtle variations.

In the siting process presented in this report the participants select the criteria. They do not do so in a vacuum. Typically there will be studies for the same type of facility in similar regions or for other facilities in the same region from which to draw. The project manager of the siting process will provide a structure for consideration of criteria and suggestions. Access to the available data and appropriate background information will be provided before participants are asked for objectives and criteria.

Also, development of the criteria is usually assisted by a group of experts trained in different subject areas such as terrestrial ecology, engineering, and climatology. These professionals form the "siting team", responsible for technical support in conducting the siting study. They will often belong to the staffs of the participants.

The siting team, however, usually does not make decisions concerning the relative importance of criteria. These decisions are made by the participants in the siting process; the developer, interest groups, and government officials, who guide the overall direction of the site selection study. Since the participants may not be experts on specific issues and are certainly not informed about all issues, siting team members must carefully explain the technical implications of various decisions to them.

Criteria for siting energy facilities usually include engineering and economic as well as natural and social environmental considerations. This study focuses on environmental criteria, which are only one component of the siting decision. In an actual siting exercise the environmental criteria would have to be integrated with other types of criteria. As was confirmed by reviewers of drafts of this study, there is no commonly accepted definition of "environmental," since aspects of the natural environment influence engineering and economics, and vice versa. For example, the amount of dredging required to provide access for a vessel of a certain draft (an economic or engineering criterion) influences the disturbance of aquatic species in the dredged channel (an environmental criterion). The environmental criteria in this report do not include these indirect relationships.

Environmental criteria presented in the following sections have been identified for siting in the Canadian Arctic. It would be impossible at this time to construct a comprehensive list of specific factors that should be used throughout the Arctic, although examples of probable criteria are provided. Specific criteria can be expected to differ from the examples depending on the following: 1) type of facility development; 2) geographical region of the Arctic; 3) size of the region of interest; 4) extent of environmental concern; 5) existence and form of available environmental information; and 6) the participants.

A major concern in structuring the criteria involves the specific type of oil and gas facility for which a site is needed. Once the specific facility type has been identified, criteria can be developed that reflect environmental concerns for that facility. Since oil and gas support facilities can include a wide variety of development types (e.g. offshore/onshore, water/road/air access, compact/linear, etc.), specific criteria must be developed for each siting study. The most significant criteria development difference probably occurs between pipeline/haul road routes and site-related facilities. The selection of pipeline/haul road routes is primarily a mapping exercise in which lands most sensitive to development are eliminated or avoided in a screening process. Criteria for

pipelines and haul roads, therefore, should be mappable on a regional scale to allow an environmentally acceptable route to be selected. On the other hand, siting studies that select compact facility site locations generally limit regional screening to the initial phases of site selection and utilize site evaluations in detailed stages of the investigation. For these types of facilities, criteria can include both those that can be regionally mapped and more detailed criteria that reflect environmental conditions at a specific site. Environmental criteria will not necessarily vary between facilities to the extent that engineering or economic criteria when the facilities are built in the same types of areas (e.g. shorelines, offshore, inland).

The selection of appropriate criteria for conducting site selection studies in the Canadian Arctic will depend on the availability of existing information. In some areas, such as the Mackenzie River Delta, a greater number of environmental investigations have been conducted than in more remote regions of the Arctic. It is within these better known regions that the most detailed criteria can be developed. Other areas may have to rely on more general criteria that can be developed from a less specific data base.

There are a number of choices that must be made in selecting criteria. In many situations a number of different criteria can be used to assess the same issue. The criteria selected most often reflect the availability of information. For example, productive marine ecological communities could be effectively identified according to productivity and ocean upwelling. This information, however, may not be available for many regions of the Arctic. A second approach may involve identifying concentrated feeding grounds of marine mammals, fish and sea birds. Since these animals can be expected to feed within more productive marine waters, concentrated feeding areas are usually indicative of high marine productivity.

The level of significance that can be attributed to individual issues can also differ according to the specific criteria. It is therefore impossible to consider one issue as more important than another until the specific criteria have been developed. For example, known concentrations or breeding areas of endangered species are critical to their survival and usually constitute exclusion criteria. This detail of information, however, may not be available for some site selection studies. The issue of protection of endangered species could then be assessed according to the availability of optimal habitat within the species range. The probability of the endangered species actually inhabiting optimal habitat, however, is far less than under the former situation. The significance or

importance attributed to this criterion should be reduced accordingly. In some situations, where differences are very subtle or fail to adequately differentiate lands, it may be appropriate to defer the criterion until the site evaluations stage, when more detailed information can be included in the assessment.

Criteria described in this report were developed by reviewing environmental information sources describing arctic regions of North America. All were either mapped or mappable, based on the reports reviewed. Our focus was on regional data and screening criteria, since site evaluation criteria are quite variable. While issues and subissues often apply to most geographical regions of North America, the specific criteria are unique to arctic regions. The environmental consequences of oil and gas development in arctic Alaska are particularly valuable in identifying areas of environmental concern. By reviewing the environmental impacts of Alaskan development, similar problems, criteria, and data needs in the Canadian Arctic were anticipated by analogy.

There has been no attempt within this investigation to assess in detail the adequacy of existing data sources for conducting site selection investigations in the Canadian Arctic. It is apparent, however, that a significant portion of recent Canadian Arctic research has been concentrated within the Beaufort Sea/Mackenzie River Delta region. The data base available for this area may permit the use of more detailed criteria than data bases of more remote arctic regions would. One reviewer of this report pointed out that the data base for the arctic marine environment is not comparable to that for the terrestrial environment. His concerns were that marine impacts are both more probable and of larger spatial effect than terrestrial impacts and that the process will be biased toward terrestrial criteria because of better data availability (Wainwright, 1982). This is one of the factors that would have to be taken into account by participants in the siting exercise.

A bibliography has been provided to acquaint the reader with some important reports that may be helpful in conducting site selection studies in the Canadian Arctic. One of the most useful sources of information is expected to be the Canada Land Data System (CLDS). This computer-assisted system can produce digitized land classification and other maps that may prove useful in implementing specific criteria. Other sources of data on biological, physical and social issues that are available for much of the Canadian Arctic include the Northern Land Use Information Series Maps. The Inuit Land Use and Occupancy Project (Milton Freeman Research Ltd., 1976) provides regional maps

identifying environmental and social factors that should be considered for developing socio-cultural and subsistence economy criteria.

3.2 Application of Environmental Criteria

Comprehensive site selection studies within the Canadian Arctic require that criteria be developed to reflect the environmental concern of the region. The format in which these criteria are stated and the ways in which they are applied depend on the siting methodology and the objective that each criterion supports. Perhaps the most familiar and the easiest type of criterion to understand and apply is one that specifies an absolute limit or threshold of acceptability (i.e. an exclusion criterion). This is the typical format of a regulatory criterion; however, a criterion can also be applied in terms of a ranking of situations in the order in which they contribute to realizing an objective (e.g. decreasing density of waterfowl use represents less likelihood of adverse impacts, although no specific density automatically becomes unacceptable).

Common general variations of criteria application are based on:

- | | |
|--|--|
| incidence or occurrence | - The criterion is applied as the presence or absence of a feature in the study area. |
| proximity | - The distance from a feature to the site is applied as a criterion--either closer is better or farther away is better. |
| buffering | - A criterion is developed based on the incidence of an important feature and the distances from the feature that are necessary to protect it. |
| intensity of use or
relative significance | - Where all or most potential sites within a region of interest have some feature (e.g. they are subsistence hunting areas for caribou), then the criterion must be some measure of relative significance, such as density, within areas possessing that characteristic. |
| surrogates or indicators | - A criterion is applied as an indirect and usually imperfect substitute for a more direct criterion, usually because of lack of data. |

The major environmental considerations (e.g. terrestrial ecology) and issues (e.g. critical wildlife habitat) around which criteria can be developed are presented within this section. The environmental considerations described in this report are as follows:

- Terrestrial Ecology;
- Aquatic/Marine Ecology;
- Socio-cultural Resources;
- Subsistence Economy Effects;
- Hydrologic Effects;
- Climatology;
- Nonrenewable Resources; and
- Terrain/Land Classification.

A list of prominent issues follows each consideration. These lists are subject to modification depending on the requirements of each siting study. A brief discussion under each issue includes a rationale for it, data limitations, and example criteria. Criteria are listed by consideration in Appendix III as a summary of this section. This preliminary listing of criteria should prove helpful as a first step in planning site selection studies.

3.2.1 Terrestrial Ecology

- Parks, Reserves and Natural Areas
- Rare, Endangered, and Endemic Species or Communities
- Critical Wildlife Habitat
- Distribution and Density of Important Animal Species
- Sensitive Plant Communities
- Productive Ecological Communities

Parks, Reserves and Natural Areas. There are a number of national and international organizations and government agencies, such as Parks Canada, that administer or have identified arctic sites that contain natural features or biological values surpassing those of surrounding lands. They therefore provide a readily available source of data for delineating lands that contain significant biological resources. Examples of some existing or future land designations that should be considered as siting criteria include:

- National and Territorial Parks;

- Wildlife Areas and Sanctuaries;
- Reserves;
- Natural Areas of Canadian Significance (NACS);
- Natural Sites of Canadian Significance (NSCS);
- International Biological Program (IBP) Sites;
- Areas of Wildlife Significance;
- World Heritage Natural Sites; and
- UNESCO's Man and the Biosphere (MAB) Program.

The importance of disturbing these areas is expected to vary according to a variety of factors, such as size, regional distribution, regulatory controls, and ecological sensitivity. It, therefore, may become appropriate to use only those land classifications of greatest significance in the regional screening and defer remaining areas for consideration later during site evaluations.

Since the purposes of these areas are preservation, recreation, and education they could preclude non-renewable resource development and related uses. The policy of the Canadian government is to assess nonrenewable resource potential of an area prior to designation of national parks (Working Group on the Lancaster Sound Regional Study, 1980).

The parks, preserves and natural areas above would probably be applied as exclusion criteria. The higher relative significance of these areas verses other parts of the region has already been established and boundaries of the areas are based on considerations such as diversity of natural regions, critical habitats, uniqueness and scientific research value. The units could not be subdivided nor the boundaries changed without additional study.

Rare, Endangered, and Endemic Species or Communities. Some organisms currently exist at very low population levels or in restricted areas because of the actions of man or through natural processes. Since population levels are low or located in isolated areas, disturbances to these organisms attributable to facility development would produce a greater adverse effect on the overall population than similar disturbances to more common species. The most significant possible adverse effect may be a continued decline in the population, eventually resulting in extinction.

The initial step in this evaluation involves the review of rare or endangered biota lists that have been developed by government agencies or private organizations. If

species included on these lists are known or suspected to inhabit the region, further evaluations should be made as to possible adverse effects from facility development. The overall importance, though not necessarily the biological importance, of this issue depends on the protection afforded to these species by regulatory agencies. There appear to be two lists of arctic species that should be consulted to assess this issue. The Committee on Status of Endangered Wildlife in Canada has developed a list of endangered and threatened species at the federal level. While there is no legislation specifically directed at endangered wildlife, these species are or can be afforded some protection under the Canada Wildlife Act or the Migratory Bird Convention Act. The second set of lists have been developed by territorial governments and include those species over which the territorial government exerts total regulatory control. Although not specifically a list of endangered species, these lists reflect those species of economic importance or public awareness for which concern on population levels exists. Records of the distribution and observations of these species should be used to avoid lands on which they are found. If adequate records do not exist, it may become appropriate to identify optimal habitat within the region as a screening or evaluation criterion. Species on these lists that are found in arctic regions include:

Federal

- barren ground grizzly (not classified)
- Peary caribou (threatened)
- Eskimo curlew (endangered) (possibly extinct)
- Arctic peregrine falcon (endangered)

Northwest Territories

- barren ground caribou
- musk-ox
- polar bear
- wood bison (only in the Mackenzie Bison Sanctuary along the northwest shore of Great Slave Lake)

Yukon Territory

- musk-ox

Another criterion is the occurrence of endemic species or plant communities. These organisms usually represent a relic of former periods when climate was favorable to their existence. They now form isolated areas in which disturbances could possibly affect a significant portion of the entire regional population. Within the Canadian Arctic some of these organisms are often located within unglaciated mountainous areas in the Yukon Territory (Government of Yukon, 1980). The incidence of important habitats and areas essential to the survival of rare, endangered or endemic species or communities is likely to be applied as an exclusion criteria with an appropriate buffer zone specific to each species or community also excluded.

Critical Wildlife Habitat. Some animals that normally range over a wide area congregate in large numbers during certain times of the year. Disturbances during this period could significantly alter the viability of future populations. By avoiding these critical habitats, the regional impact of altering these animal populations can be eliminated or reduced. In most situations, these species are most sensitive to disturbances during nesting and reproduction and at staging areas (geese). There are a number of animals that could be evaluated within this issue. There, appears to be two groups of animals that are of primary concern: caribou and waterfowl. These are cited as examples of the types of concerns.

Caribou are most sensitive to disturbance during calving and pre- and post-calving migrations. The importance of disturbing caribou during these periods can be understood by reviewing the consequences of the Alaskan pipeline. Caribou tend to avoid the Prudhoe Bay area and pipeline corridor road, especially cow caribou with calves. Formerly, this area was used for calving and post-calving movements. Most caribou also avoid the Trans-Alaska Pipeline System pipeline corridor, which has fragmented the Central Arctic caribou Herd into east and west segments, which move independently of each other. While migration routes and calving areas may be appropriate screening criteria (calving areas would probably be exclusion areas, whereas migration paths would be avoided where possible by pipelines and other linear construction but would not necessarily be excluded), more detailed evaluations could include the avoidance of high ridges, sand dunes and persistent snowfields in their summer range. These areas provide some of the only areas in which caribou can escape from insects during the summer. Major wintering areas also represent concentration of caribou during times when their distribution is limited.

The Arctic Slope also provides critical habitat to large populations of waterfowl and other birds for nesting, molting, staging and feeding. Development within coastal wetlands could disrupt birds and might cause desertion of nests, abandonment of feeding, resting and molting areas, and possible overuse of adjacent undisturbed areas. The detail of this evaluation will depend, in part, on the availability of information. If nesting areas of specific species are known, avoiding known nesting areas of birds, such as snow geese, that are particularly sensitive to disturbance will be a criterion. In many situations, however, this information may be unavailable and the location of potential nesting areas, estimated from ground cover and terrain, will be used as a criterion.

There are a variety of possible landforms or vegetative covers that provide critical habitat for a number of animal species. The siting team must review a list of those important animals that inhabit the region and then determine the types of critical habitats they wish to suggest as criteria. Some of the landforms they may wish to include are ridges, pingos and caves (denning locations for foxes, wolves and bears) and cliffs (raptor nesting). Another example involves critical habitat for muskrats. In the northern Yukon Territory, muskrats are restricted in winter to waterbodies between one and two metres in depth. Shallower lakes completely freeze, while deeper waters lack food resources for local muskrat populations (emergent and submergent vegetation) (Lands Directorate, Map 101A accompanying text).

Distribution and Density of Important Animal Species. Although not under consideration as critical habitats or areas essential to species with designated status, higher density occurrences of important animals having a broad range within the region of interest and the distribution (including restricted seasonal distributions) of animals having a limited range within the region of interest are useful siting criteria. They would ordinarily be applied by: (1) favouring areas of lower density for individual species; (2) favouring sites used by only one species over areas used by many species; (3) favouring areas intensively used by one species over those used by another based on a (subjective) relative assessment of the importance and sensitivity of species; or (4) avoiding the areas used by species with limited distribution.

Data on density and distribution is gathered based on surveys (flyovers), knowledge of historic limits of distribution, inferences from habitats and sightings.

Examples of these types of criterion are duck distributions and densities and summer home ranges of wolf packs. In a study for the National Petroleum Reserve in

Alaska (US Geological Survey, 1979) diving duck densities were mapped in three categories ranging from less than 5 to greater than 15 per square mile; similar maps were produced for other bird species. The same study indicated the limited summer home range of certain wolf packs.

Sensitive Plant Communities. Certain plant communities are particularly sensitive to disturbances associated with development projects. Resulting effects of facility development can, therefore, be minimized by avoiding particularly sensitive plant communities and locating the facility within a cover type less sensitive to disturbances. Past experience has shown the Arctic tundra in general is sensitive to most disturbances. If vegetative cover is damaged and mineral soil exposed (or on barren ground), subsidence and erosion usually follow. Tundra, however, is probably too broad a factor to evaluate. A more appropriate approach would be to identify a specific component of the tundra landscape that is particularly susceptible to disturbance.

Another approach to assessing sensitive cover types involves identifying those habitats that are particularly susceptible to degradation by sedimentation and contaminated runoff. This is expected to include wetlands such as freshwater marshes and wet tundra. It is interesting to note that the US Army Corps of Engineers has designated all nonalpine tundra areas up to 80 miles inland from the Beaufort Sea coast as wetlands.

The possibility of sulphur dioxide emissions at some facilities suggests a need, in some situations, for an assessment of possible adverse effects on plant communities. Lichens are particularly sensitive to sulphur dioxide and form a prime winter caribou food in the region. It, therefore, may be appropriate to avoid those cover types in which lichens form a major component.

Productive Ecological Communities. Net primary productivity within tundra plant communities is far from uniform throughout the Arctic. The standing crop of plants increases about one hundredfold from polar desert areas to shrub tundra. Areas of high primary productivity can also be expected to provide increased food supplies for consumers such as caribou and musk-oxen. These lands, therefore, may support higher faunal densities than nearby less productive tundra areas. By avoiding areas of particularly high primary productivity, the regional adverse effects of displacing or disturbing plant and animal communities can be minimized. A basic approach to evaluating this issue is through the identification of percent vegetative ground cover. In

general, the floodplains and deltas of northern rivers are areas of high productivity set within the less productive tundra landscape. Even within the High Arctic, however, meadows with a continuous cover of mosses, sedges and grasses have been identified as highly productive systems. For example, meadows with a relatively continuous cover comprise two percent of the Queen Elizabeth Islands, but are credited with providing most of the primary productivity for the rest of the food web on land.

3.2.2 Aquatic/Marine Ecology

- Parks, Reserves and natural Areas
- Rare and Endangered Species
- Critical Habitats
- Productive Ecological Communities

Parks, Reserves and Natural Areas. Although these lands are assessed within the terrestrial ecology criteria, the siting team should be aware that part, or all of these sites form marine or aquatic systems of exceptional biological value. They, therefore, will also provide an overview of some of the more important aquatic or marine areas in the region. The selection of some of these areas, Natural Areas of Canadian Significance (NACS) and International Biological Program (IBP) Sites, was directed specifically at identifying outstanding marine systems. These areas are particularly valuable for delineating recognized waters of biological importance in the Arctic. A complete description of various sites that might include aquatic or marine areas can be found within the terrestrial ecology issue.

Rare and Endangered Species. Because of the actions of man or through natural processes, these organisms currently exist at very low population levels or in restricted areas. Since population levels are low or located in isolated areas, disturbances to these organisms attributable to facility development, would produce a greater adverse effect on the overall population than similar disturbances to more common species. The most significant possible adverse effect may be a continued decline in the population, eventually resulting in extinction.

The initial step in this evaluation involves the review of lists for rare or endangered biota that have been developed by government agencies or private organizations. The bowhead whale appears to be the only species of marine biota that has been classified endangered in the Arctic. This whale was designated as endangered by the

Committee on Status of Endangered Wildlife in Canada. While there is no federal legislation specifically directed at endangered wildlife, this whale is or can be afforded some protection under the Canada Wildlife Act.

Bowhead whales frequent the eastern Beaufort Sea during summer and there is grave concern of probable extinction in the Western Arctic. Because of their feeding habitats these whales would be particularly susceptible to an oil spill. They also avoid noise sources such as low flying aircraft. It is, therefore, important that facility development and access routes attempt to avoid concentrations of these whales.

Critical Habitats. There are a number of fish and marine mammals that congregate in groups during certain times of the year for survival or to complete the reproductive cycle. Disturbances during these activities could significantly alter the viability of future populations. Some of the important activities that need to be considered in identifying critical habitat include:

- migration;
- egg incubation;
- spawning;
- overwintering;
- calving (whales); and
- pupping (seals).

Development activities should attempt to avoid locating new facilities near waters intensively used for these activities, as well as outside such areas but requiring access through or creating adverse effects on waters of critical importance. In the case of pipeline routing, care should be taken to avoid blocking movements by anadromous fish.

Anadromous fish tend to migrate along nearshore areas of the coast. The construction of causeways or other structures in the coastal zone may have the potential to block or delay the movement of fish along the coast. Investigations of a causeway at Prudhoe Bay, Alaska, however, have concluded that the causeway does not block or delay the movement of fish along the coast. Anadromous fish return each fall to freshwater to spawn and overwinter. The Mackenzie Delta provides critical spawning and overwintering areas for whitefish, burbot and Arctic char. The presence of open water or discontinuous unfrozen pools under the ice is particularly critical to the survival of these fish. In the Northern Yukon Territory these areas have been identified along rivers utilizing Landsat mosaics and would provide a valuable source for detailed evaluations.

Attempts should also be made to minimize the disruptions of whale and seal migration, calving and pupping areas to the fullest extent possible. The turbid waters of Mackenzie estuary, especially Mackenzie Bay, provides a major calving area for beluga whales.

Productive Ecological Communities. The major control over marine productivity is the degree of vertical stability of the water layers. The deep waters of the Arctic Ocean are rich in nutrients, but must be brought up to the level where there is sunlight for production by plants. In general, regions of highest productivity occur where arctic waters meet subarctic waters. Some of these areas can be found in Hudson Strait, off the southeast tip of Hall Peninsula, up the central part of Davis Strait and Baffin Bay, and off the coast of Alaska, Yukon and the Northwest Territories as far east as Cape Bathurst. The importance of areas of particularly high productivity are often reflected in their use as concentrated feeding areas by fish, marine mammals and birds. Because of the importance of these areas in providing food resources to animals of the region, and the sensitivity of these areas to pollution and possible oil spills, regions of particularly high productivity should be avoided if possible, when selecting a facility site and access routes.

Productivity of freshwater lakes may be more difficult to assess. During the routing of pipelines and roads, the best approach is to avoid as many lakes as possible. Pipelines and roads should also minimize stream and floodplain crossings.

3.2.3 Socio-cultural Resources

- Inuit and Dene Settlements (permanent communities, campsites, seasonal settlements)
- Sites of Symbolic, Cultural or Religious Significance
- Sites of Historical or Archeological Significance
- Recreation and Tourism

Inuit and Dene Settlements. The isolation of the Inuit within arctic regions has permitted them to preserve much of the culture that has been lost to other native people of North America. The desire to retain their cultural heritage for the benefit of future generations is a fundamental objective of the Inuit. The lifestyle retained by the Inuit through isolation in the Arctic is particularly sensitive to rapid modernization that may come with facility development. To a large extent, the impact may depend on the degree to which the development is either isolated from or integrated with the community. The

most serious effects, however, can be expected within small communities with subsistence economies. By avoiding these communities, adverse impacts can be minimized. Conversely, larger communities with a more diverse population and stronger infrastructure may view facility development as a positive benefit. Similar considerations apply to the Indian (Dene) population and their settlements. The site selection criteria should incorporate both adverse and beneficial factors of locating new facilities in or near existing settlements.

The criteria under this consideration would typically be: 1) proximity to Native settlement(s); 2) the size of the settlement; 3) the existing degree of access versus that available with facility development; and 4) the extent to which the development might help or disrupt the local economy. Acceptance or rejection of the facility by the community would determine the direction in which the criteria are applied.

Sites of Symbolic, Cultural, Religious, Historical or Archaeological Significance. The relevant criteria involve avoiding sites of symbolic, cultural, religious, historical and archaeological significance and a reasonable buffer around them. These sites are valuable cultural assets to the local population and can usually be avoided since they are often restricted to specific site locations. However, development in the vicinity may increase both access and awareness of the existence of such resources and consequently increase the chances for intentional or incidental destruction or damaging of the resource. Some of these sites are usually known from traditional land use inventories and surveys by scientific researchers. In some instances these sites may only be discovered by coincidence, often in conjunction with resource exploration or development.

Recreation and Tourism. The vastness, diversity of scenery, sparsity of human population and abundance of wildlife in a relatively pristine setting provide significant primitive recreation and sightseeing opportunities in the Canadian Arctic. The primary constraints to recreation and tourism are reasonable access and possible conflicts with traditional land use. For example, sport hunting conflicts with subsistence use both in terms of the philosophy of the Natives and possible scarceness of the biotic resources.

Typically, to apply recreation and tourism potentials as criteria, areas that present unique terrain, scenic resources (landforms, views, assemblages of ecosystems, etc.) or biological resources not highly subject to adverse effects from tourism are identified to be avoided by incompatible uses. Multiple use areas for hydrocarbon development and recreational uses may be encouraged to concentrate the effects of

development and increased access in controlled locations. Some recreation opportunities will be recognized in the creation of parks and reserves as covered in other criteria.

3.2.4 Subsistence Economy Effects

- Subsistence Hunting Areas
- Trapping Areas
- Subsistence and Commercial Fishing Areas
- Other Subsistence Use Areas

Hunting and Trapping Areas. There is an inseparable relationship between ecological resources and Inuit and Indian lifestyles that must be acknowledged prior to assessing potential effects of facility development on the Inuit and the Dene. The potential degradation or elimination of fish and wildlife on which they depend is often identified as their primary fear of development projects. Although important domestic and commercial, hunting and trapping areas for many arctic regions have already been delineated, this information may be too generalized to accurately evaluate potential adverse effects from facility development at specific site locations. If greater detail is required, criteria can be developed that reflect the importance of site-specific factors. For example, the most important animals trapped within the Mackenzie River Delta are muskrat and Arctic fox. Adverse effects from facility development that are responsible for a decline in the muskrat and fox populations can also be expected to significantly alter Inuit lifestyle. The same approach can be taken for evaluating subsistence hunting. For example, within the Mackenzie River Delta the principal animals hunted by the Inuit are whale, caribou, seal, polar bear and waterfowl. The perpetuation of these species on lands that can easily be reached from Inuit settlements is necessary if the communities are to continue subsistence hunting without moving the settlement.

Examples of criteria for the objective of maintaining subsistence hunting would be: 1) areas in which specific species are hunted (this criterion would be applied based on the relative importance of specific species to subsistence and maintenance of the culture); 2) intensity of subsistence use (primary/secondary subsistence areas); 3) the number of subsistence species available in the vicinity; 4) the number of villages or settlements that use the area; or 5) proximity of subsistence areas to settlements and traditional access routes.

Traplines will probably be too extensive to be completely avoided, particularly for shoreline facilities. Applicable criteria would then have to be based on historic

economic value of various segments, the relationship of specific segments to the overall trapline lengths and the species being trapped.

Fishing Areas. Important domestic and commercial fishing grounds have also been delineated for most areas within the Arctic. Again, these areas may be too generalized to adequately assess the importance at specific site locations. By identifying the specific fishery resource and the degree to which nearby Inuit communities depend on the fishery, the overall importance to the continued existence of the settlement can be identified. Fish species of particular value in subsistence fishing in the Arctic are Arctic char, whitefish, grayling, burbot, pike and salmon. Whitefish are of particular value within the Mackenzie River Delta. Commercial fishing operations are often of limited size in the Arctic; however, they may be very important to local economies. Within arctic Alaska a limited commercial fishery has developed around Arctic cisco, salmon and inconnu. Criteria for fishing areas will be of a similar type to those for hunting areas.

Other Subsistence Use Areas. In addition to hunting, trapping and fishing, Natives of the Arctic carry on other subsistence activities such as berry gathering and structural material collection. Differences in the significance of these activities would be expected from settlement to settlement. Usually they are secondary subsistence activities.

3.2.5 Hydrologic Effects

- Flooding
- Erosion
- Water Quality/Surface Water Use

Flooding. Flood waters can damage structures, alter landforms, transport contaminants from the facility, and destroy human life and ecological communities. There are two relevant types of flooding that should be given consideration during selection of a facility site: storm surges and river flooding. In coastal areas, development facilities should be located inland of the storm surge zone. Storm surges can cause changes in sea level as great as 1.5 m over a period of a few days on the Beaufort Sea coast. A storm at Barrow, Alaska in 1963 caused a tremendous surge of 3.4 to 3.7 m that flooded many areas. Guidelines for siting oil debris disposal sites on the Beaufort Sea coast between the Alaska-Yukon border and Cape Bathurst suggest that these facilities be located at least 3 m above mean sea level if the storm surge zone is unknown (Environmental Impact Control Directorate, 1978).

Inland oil and gas support facilities should attempt to avoid alluvial fans and active flood plains. Extensive flooding, especially in larger stream and river channels, occurs during spring breakup between May and early July. Flooding often extends for considerable distances, often up to several miles on each side of the channel. Tundra flooding is also common during the snowmelt season. Guidelines for selecting the aforementioned oil debris disposal locations suggest that sites be at least 1.5 m above and 100 m away from the high water mark of streams, rivers and lakes.

Erosion. Facility development or pipeline/haul road construction will expose soils to erosion by running water or melt by above-freezing temperatures. Thermokarst subsidence, gullyng, or slumping may eventually result. Once the arctic ground has been disturbed and soils exposed, recovery will be an extremely slow process. In many arctic areas, scars left by the passage of vehicles are clearly evident after 20 years. The avoidance of areas particularly susceptible to erosion is, therefore, desirable to minimize potential adverse effects on surrounding drainages and maintain the integrity of natural systems. There are a number of factors that provide an indication of the erosion potential within arctic regions. Some of the factors of particular value include local relief, soil texture, vegetation cover, soil water, and depth to permafrost. Specific landforms that should be avoided according to siting guidelines for oil debris disposal sites on the Beaufort coast include recently drained lakes, taliks or large icing zones and low lying sedge meadows. If information of this detail is unavailable at a regional scale, estimates may have to be made from more general information such as topography.

A rather unique erosion problem must be considered when locating development facilities along the sea coast. Beaches of the Beaufort Sea Coast thaw to a depth from five to ten feet in summer months, which allows mechanical erosion of thawed beaches and thermal erosion of coastal banks and bluffs to cause a continuing problem of coastal retreat. Recession rates are greatest in banks containing fine-grained sediments such as silt, which contain the greatest amount of ice. Studies along the Beaufort Sea coast between the Alaska- Yukon border and Cape Bathurst have identified the maximum rates of mainland coastline retreat for cliffs without beaches to be 5.3 m/yr and for cliffs with beaches to be 3.3 m/yr. Coastal erosion rates of 30.5 to 50.3 m have been recorded at some promontories during storms along the Beaufort coast. Lands estimated to be lost to coastal erosion over the projected life of the development facility should be avoided during site selection.

Water Quality/Surface Water Use. Surface water is the primary source of water to Inuit communities and other settlements since permafrost markedly affects the distribution of groundwater in the Arctic. Few Arctic communities have municipal water supplies: most acquire their water by hauling it from nearby lakes and streams in summer and by chopping holes through the ice, or by melting snow or ice during winter. Although water quality varies as to location, water from surface sources in the Arctic is generally of acceptable chemical quality. Since development of a new facility can be expected to form a potential source of contaminants that could degrade water quality, an attempt should be made to avoid locating new development facilities in the immediate vicinity of surface water supplies. Guidelines for selecting oil debris disposal sites on the Beaufort Sea Coast between the Alaska-Yukon border and Cape Bathurst recommend that surface waters within 3 km or directly upstream of a settlement be avoided unless a detailed review of potential contamination of drinking water has been completed.

3.2.6 Climatology

- Air Quality
- Ice Cover and Movement
- Ice Scour

Air Quality. Air pollution is generally not considered a problem in the Arctic and probably will not be in the future except under special circumstances. Temperature inversions, which are common in the Arctic, particularly during the winter, often limit the vertical distribution of pollutants. While winds often disperse these pollutants above open lowlands, a temperature inversion could trap pollutants in areas where dispersion is limited by topography, such as river valleys. Deep valleys and canyons should be avoided during the selection of oil and gas support facilities that form a source of atmospheric emissions.

Ice Cover and Movement. Ice is one of the major constraints to developing oil and gas support facilities within arctic regions. It becomes particularly important in the planning of offshore structures and shipping access. Areas that pose a hazard or obstacle to shipping or development due to particularly high concentrations of sea ice or patterns of ice drift should be avoided during the development of oil and gas support facilities.

The detailed distribution of sea ice depends of meteorological conditions, currents and tides, and the topography of the sea floor. Inland of the 50 m isobath has

been identified as the outer edge of the stable floating fast ice along the Beaufort Sea coast in Alaska.

Consolidated ice edges (i.e. the boundaries between landfast and drifting ice) provides critical habitat for many species, including the ringed seal. The fast ice edge also forms a barrier to movement. Criteria related to ice cover and movement are applied as indicators of environmental hazards or surrogates for biotic information.

Ice Scour. One of the primary factors governing suitability for locating marine pipelines is the occurrence of seabed ice gouges. These gouges can be found from nearshore to approximately the 60 metre isobath along the Beaufort Sea coast. In arctic Alaska, they are generally oriented parallel to the coastline due to the westward drift of the polar ice pack. Inside the grounded ridge zone, however, there is often a southwestward trend toward the shoreline. The gouges are usually deeper than one metre outside the grounded ice ridge and less than one metre on the shoreward side of the zone. Extreme gouge depths have reached 5.5 metres on the outer shelf. Areas along the coast in which ice scouring is particularly prevalent should be avoided when selecting a pipeline route. By avoiding these waters, the depth of trenching can be minimized and the possibility of a disastrous spill can be reduced.

3.2.7 Non-renewable Resources

- Mineral and Non-mineral Resources
- Sand and Gravel

Mineral and Non-mineral Resources. The location of known deposits of mineral ores and other commercially viable non-minerals are valuable resources that could be mined at some time in the future. The possibility of mining these deposits should be taken into consideration during the site selection study. Sites that preclude or create an obstacle to future mining should be avoided. Additionally, oil and gas support facility sites in the immediate vicinity of deposits should take into consideration the possible value of the support facility to future mining and transportation requirements. Some of the major minerals resources of the Yukon and Northwest Territories include lead, zinc, silver, tungsten, gold, tin, coal, uranium, molybdenum and copper as well as barite which is used in well operation.

Sand and Gravel. These materials are essential for the construction of both onshore and offshore facilities. Sand and gravel pads provide a working surface for

construction that helps to prevent permafrost degradation. Offshore gravel islands provide protection against ice movements. It is therefore important that oil and gas support facility sites be located in close proximity to sand and gravel deposits that can be reclaimed and transported with minimal environmental impact. Some of the major onshore sources of these materials are stream beds, beaches, spits, barrier islands and alluvial fans. Offshore sources are also common. Removal of sand and gravel from coastal beaches can result in coastal retreat. Gravel and sand excavation from inland surficial deposits in permafrost areas may eventually trigger a new thaw lake growth cycle. Removal of sand and gravel from stream beds can cause stream damage.

3.2.8 Terrain/Ecological Land Classification

- Ecoregions
- Landform/Surface Form/Topography

Ecoregions. The Ecological Classification and Evaluation Division of Lands Directorate, Environment Canada is producing the Northern Ecological Land Survey Map Series. These maps are based on classifying land into ecoregions, which are subdivisions of ecodistricts. (Ecodistricts are usually too broad to be useful in siting.) Throughout an ecoregion there are recurring patterns of landform, soils, vegetation and water bodies. Ecoregions are classified based on these parameters:

- genetic materials;
- surface expression;
- textural modifier;
- percent cover;
- vegetation;
- lakes (percent cover, average size, shape, shore pattern, and drainage conditions);
- rivers (channel pattern, floodplain width); and
- drainage pattern.

Because of the classification scheme, the extent of the region covered and the scale of mapping, ecoregions represent subregions with variable properties from site to site. The predominant characteristics within each ecoregion are indicated as primary (1°); less common as secondary (2°); and so forth. Depending on the differences between different orders of occurrence, there may be excellent sites within ecoregions that are mostly less suitable. Ecoregion properties could be applied as a criterion after

considering the variability of the ecosection with regard to each property and the significance of the property. Ecosections would then be ranked as to their relative suitability for the facility.

Use of land classification as a criterion would be more likely for pipelines or access roads because these would traverse a wide variety of ecosections and the relative differences between them could aid route selection. However, even for facilities confined to a more compact site, there may be significant environmental differences (e.g. differences between the Mackenzie Delta and adjacent plains).

Ecosection characteristics indicate a combination of engineering and environmental considerations. For example, the geological and soil substrate provides an indication of the engineering suitability of the area. Certain substrates may not be suitable for facility development or may require expensive foundation work to establish a suitable base. Differential settlement or other problems that develop after the facility has been constructed not only contribute to the integrity of the structure, but also may be a source of sediments or contaminants that eventually degrade surrounding natural systems. It therefore is preferable, from both an engineering and environmental perspective, that the facility be located on land exhibiting optimal engineering characteristics.

Landforms/Surface Form/Topography. Although most of the terrain classification work for northern Canada is planned at a generalized level (ecosections or broader), for specific studies and regions of interest a more detailed look at topography is appropriate. As an example, a study developed for the North Slope Borough in Alaska (Environmental System Research Institute and Arctic Slope Technical Services Incorporated, 1982) included detailed analysis of landform and surface form. Landforms such as pingos, floodplains, and bluffs and surface forms such as high-centred polygons and non-patterned ground were identified for the study area based on interpretation of remote sensing imagery and ground truth. Slope zones were also mapped.

The data to support criteria based on specific topography apparently has not been compiled for arctic Canada; however, for specific facilities such as shorebases, the availability of flat land and the type of shoreform are important siting criteria. This data could be compiled once the need has been established.

In some situations it may become appropriate to identify and avoid those unstable topographic features that contain particularly large amounts of ice. Some of

these features may include thermokarst topography, ice wedge polygons, pingos, and frost mounds. Topography can also influence the suitability of permafrost lands. Topsoil above the permafrost can become saturated, causing a downslope movement of water-saturated sediments called solifluction. This can occur on slopes as gentle as three degrees.

GLOSSARY

combination of criteria levels - a collection of site attributes, including one attribute level for each criterion. Continuous scales are usually grouped in classes to avoid considering an infinite number of combinations.

continuous scale - as applied to a criterion, a scale not divided into a number of distinct possible levels.

constructed scale - as applied to levels within a criterion, a scale not based on intrinsic dividing points or levels; using levels based on subjective classification.

criterion - one standard or measure of performance on which a decision is partially based.

decision analysis - a systematic procedure for evaluating the attractiveness of alternatives based on the likelihood of possible consequences and the decision maker's preferences for the consequences.

discrete scale - as applied to a criterion, divided into a distinct or fixed number of levels, such as high/medium/low suitability; the opposite of continuous.

exclusion criterion - a criterion used by eliminating all potential sites below a certain level of performance regardless of the site or area's performance vs. other criteria.

inclusion criterion - a criterion used by including all potential sites above a certain superior level of performance regardless of the site's or area's performance vs. other criteria.

natural scale - as applied to levels within a criterion, a scale based on an inherent or intrinsic scale of performance; for example, soil drainage.

preferential independence - a condition in which the preference order between combinations of levels within two criteria does not depend on the level at which other criteria are fixed.

region of interest - the area, agreed to by the facility siting participants, that is the outer boundary of potential sites to be considered for the facility.

study area - generally the same as the region of interest; however, areas outside the limits accepted for siting that influence the region of interest may be considered part of the study area.

trade-off - choice between combinations of levels of at least two criteria (e.g. choose Criterion 1 at level B and Criterion 2 at level M or Criterion 1 at level C and Criterion 2 at level O).

utility function - a numerical function, usually scaled from 0 for the worst alternative to 1 for the best alternative, that indicates relative preferences for intermediate alternatives and the decision maker's attitude toward risk.

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APPENDIX I

**A BRIEF HISTORY OF ENERGY-RELATED
FACILITY SITING IN THE US ARCTIC**

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**A BRIEF HISTORY OF ENERGY-RELATED FACILITY SITING
IN THE US ARCTIC**

The pace of and consideration given to siting oil and gas development in the US Arctic have been greatly influenced by legislation and litigation. As a result this appendix is divided into three sections. The first presents a brief history of oil and gas-related activities in the US Arctic; the second section contains a political history of the North Slope; and the final section presents conclusions and some conjecture about the methodologies likely to be used in the future for siting energy-related facilities in the US Arctic.

History of Oil- and Gas-related Activities in the US Arctic

Arctic oil and gas exploration began in Alaska with the US Geological Survey's surface work in 1901. In 1904 oil seeps were found on what is now the National Petroleum Reserve in Alaska (NPRA). The US Navy, in conjunction with civilian drilling contractors conducted an extensive geological mapping and exploratory drilling program on the Reserve from 1944 until 1953. During 1949 and 1950, the Navy drilled several test wells south of Barrow in order to develop a natural gas fuel supply for the Navy's camp at Barrow. These wells were the first development wells in the US Arctic.

In 1964, the State of Alaska began leasing land on the North Slope believed to have a high hydrocarbon potential. In 1968, the Prudhoe Bay oil field was discovered east of the NPRA, and development of the field began in the same year. Construction of the Trans-Alaska Pipeline System (TAPS) began in 1974 and was completed in 1977. A total of approximately 2 billion barrels ($317\,800\,000\text{ m}^3$) of oil had been moved to Valdez at the end of 1981. Currently a waterflood project is planned for Prudhoe Bay. This plan calls for 2.2 million barrels ($249\,580\text{ m}^3$) of seawater and 1 million ($158\,900\text{ m}^3$) barrels of produced water per day to be injected into the formation to retrieve an additional 1 billion barrels ($158\,900\,000\text{ m}^3$) of oil from the field. The Alaska Natural Gas Transportation System (ANGTS), which includes a natural gas pipeline from Prudhoe Bay to the conterminous United State and a sales gas conditioning facility at Prudhoe Bay, is also planned. This system would transport the gas that is being reinjected into the formation to markets. Although the US Congress passed legislation containing waivers necessary to finance the project, the legislation is being challenged in the US District Court of Appeals in Washington, D.C. Kuparuk, a second smaller field west of Prudhoe also on State land, began production in 1981. The State of Alaska has held a total of five

lease sales in the Arctic region of the state. This total includes the Joint Federal/State Sale.

The first Federal OCS lease sale in the US Arctic, the Joint Federal/State Beaufort Sea Lease Sale, was held on December 11, 1979. Exploratory drilling is underway on both State and Federal tracts. Oil has been discovered on State offshore tracts, but it is not known if the discovery is commercially attractive. The first NPRA lease sale was held on January 27, 1982. Exploration is expected to begin in the fall of 1982.

The pace of oil- and gas-related activity is increasing. A number of events are planned. A second NPRA sale is scheduled for May 26, 1982. A second Federal OCS sale, Lease Sale 71, is scheduled for September 1982. Portions of the Arctic National Wildlife Refuge are currently being assessed for geologic exploration by the Department of the Interior. The Fish and Wildlife Service is preparing guidelines and an environmental impact statement for surface geological and seismic exploration. These documents are expected to be published in July 1982. Cape Lisburne, in the western part of the US Arctic, has been designated as a Favorable Petroleum Geologic Province (FPGP). This land will be leased competitively, although no date for a lease sale has been set at this time. Some additional Arctic land will be leased noncompetitively at a drawing tentatively scheduled for July 31, 1985.

The State of Alaska is planning to hold seven additional sales in the Arctic section of the State. Two of these sales are scheduled for May 26, 1982. One of these will offer approximately 1 500 000 acres (606 900 ha) in the Prudhoe Bay uplands, the other will offer approximately 56 200 acres (22 739 ha), including submerged land north of Prudhoe Bay adjacent to the Midway Islands and submerged land and upland in the Flaxman Island - Canning River region. Two lease sales, one scheduled for May 1983, the other for May 1984 will offer acreage in the Beaufort Sea. Two additional sales, one scheduled for 1985 and the other in 1986 will offer areas in the Kuparuk uplands area. Another sale, also scheduled for 1986, will offer submerged land lying offshore of the Arctic National Wildlife Refuge. The State had planned to offer submerged land in the Chukchi Sea in 1985, but this sale has been temporarily withdrawn from the leasing schedule while the State fills in some environmental information gaps relating to the area.

POLITICAL HISTORY OF THE US ARCTIC

Early Legislation

The sale of Alaska by Russia to the United States in 1867 for \$7.2 million had received little notice from the Inupiat, the Natives of northern Alaska. However, with cession of Alaska to the United States, all of its lands and water became public domain—land held and controlled by the Federal government. Transfers to private ownership or designation for specific uses required Congressional action. The Organic Act of 1884 was passed by Congress with a similar lack of attention by the Inupiat. This Act made Alaska a civil and judicial district. It did not permit natives to acquire title to land, but decreed that Natives were not to be disturbed in the possession of the land they used, occupied, or claimed.

During the early part of the nineteenth century, several pieces of legislation were passed by Congress that were to have an effect on the Inupiat. The Native Allotment Act of 1906, as amended, authorized the conveyance of up to 160 acres (64.7 ha) of public land in Alaska to each Native Alaskan. Individual Natives could acquire title to lands that they traditionally occupied or used for hunting and fishing. Approximately 200 claims were filed, but most were rejected because the applicants had not displayed exclusive use and occupancy for the required period. The establishment of the 37 000 square mile (96 000 km²) Naval Petroleum Reserve Numbered 4 (NPR-4) in 1923 precluded future appropriation of land, including Native allotments within NPR-4 boundaries.

Under the terms of the Indian Reorganization Act of 1934 (IRA), also called the Wheeler-Howard Act, which was extended to Alaska in 1936, Eskimo were given the right to draft village constitutions and by-laws. Barrow formed an IRA corporation in 1940.

In 1942, an opinion issued by Nathan R. Margold, Solicitor of the Department of the Interior, concluded that original occupancy under the Organic Act of 1884 established possessory rights in Alaska waters and submerged lands that such rights had not been extinguished by any treaty, statute, or administrative action. This opinion strengthened Native arguments for title to land.

By 1949, the Secretary of the Interior had created reservations for Alaska Natives under the terms of the Indian Reorganization Act of 1934. Only one village, Hydaberg, accepted a reservation, but a 1952 ruling of the US District Court found that

the reservation had been created illegally. This decision ended the practice of creating reservations to dispose of aboriginal or possessory rights.

Statehood

Alaska was proclaimed the forty-ninth State of the United States on January 3, 1959. The State constitution, approved by the voters in 1955, took effect immediately. However, the issue of land claims was still unresolved. The 1958 Statehood Act authorized the State to select 104 million acres (42 078 400 ha) of land from a public domain of some 375 million acres (151 725 000 ha). The Act also reaffirmed Native rights to land, but it did not contain any provision for Native land selection. This set the stage for direct clashes between the Natives and the State government.

In 1960, the Atomic Energy Commission (AEC) put forth a plan to use nuclear explosives to dredge a harbor at Point Hope. Contamination was anticipated to spread approximately 300 miles (483 km) inland, effectively wiping out caribou migration as a food resource of the Natives. As a result, a group of Natives formed the Inupiat Paitot—the first Native regional organization of the North Slope. Point Hope leaders were joined by representatives from Barrow and Wainwright in opposing the proposed project. Meetings of the Inupiat Paitot enabled members to share concerns about a number of issues. The group was disbanded when the AEC dropped its proposal, but the meeting of the group led to the establishment of the first Native newspaper in the State, the *Tundra Times*. This newspaper became an important instrument in the growing Native displeasure with the State concerning land claims.

The State's land selections under the Statehood Act were not to be transferred until January 1984. The Act called for a lengthy and complex process involving notification, adjudication of conflicting claims, tentative approvals, and surveys. However, because the State needed revenues, land having a potentially high commercial value was quickly selected. Alaska's Indians and Eskimos, who maintained aboriginal title to lands under the Federal acts discussed earlier, had filed claims to 122 million acres (49 300 000 ha) of land before the 1951 filing deadline of the Indian Claims Commission. These claims were still pending.

By 1966, a total of 272 million acres (110 000 000 ha) had been claimed by the Natives, either directly or in response to the land selections the State was making. The State's plans to sell oil and gas leases on land it claimed on the North Slope resulted in further protest from the Natives. Consequently, Secretary of the Interior Stewart Udall

put a moratorium on transfers of all public domain lands in Alaska until the matter of Native ownership was settled. Bureau of Land Management offices in Anchorage and Fairbanks were instructed to suspend all final actions, including granting of tentative approvals on State selections, mineral leases, and issuing of final patents. Federal leasing activity in the North Slope area was curtailed because of this decision.

The State, however, went ahead on its leasing program on tentatively approved lands. It leased 20 tracts on the North Slope, including those in Prudhoe Bay, where oil was found in 1968. The State's 1966 lease sale also led to the formation of the Arctic Slope Native Association (ASNA). ASNA was primarily a land claims organization, one of a number of regional land claims organizations that Natives were forming throughout the State. In addition to the regional Native organizations, a statewide Native organization, the Alaska Federation of Natives (AFN), was also formed.

ASNA claimed that 58 million acres (23 400 000 ha)—all of the North Slope—belong to the Inupiat by aboriginal right. In addition to its campaign for land, ASNA called for jobs, housing, and schools for North Slope Natives. Loss of land was equated with loss of and a decrease of an already low standard of living.

The Alaska Native Claims Settlement Act

The Secretary of the Interior's administrative freeze on Alaska land transactions and the discovery of oil at Prudhoe Bay precipitated a settlement of the claims. As long as the land freeze remained in effect, construction of the Trans-Alaska Pipeline could not begin. On December 19, 1971, President Nixon signed the Alaska Native Claims Settlement Act (ANCSA) into law. The Act established 12 regional corporations within the State and an additional corporation for non-resident Natives; it also required all Native villages to form village corporations that, with the advice of the regional corporations, were to make land selections and plan for the use of the money received under ANCSA.

Village corporations receive title to 22 of the total 40 million acres (8 901 200 of the total 16 184 000 ha) under the land settlement portion of ANCSA. The land going to villages is determined by population, and only rights to the surface are conveyed. The subsurface rights belong to the regional corporation. One of the most significant changes resulting from the 1971 land claims act was the creation of economic organizations operating for profit. Currently, 190 Native corporations (12 regional, 178 village) operate in the State.

The Trans-Alaska Pipeline Authorization Act

The discovery of oil at Prudhoe Bay caused the formation of the Alyeska Pipeline Service Company by a consortium of companies sharing interest in the Prudhoe Bay field. The consortium chose a route for the pipeline and applied for a 54 foot (16.5 m) pipeline right-of-way from the Department of the Interior along with a request for special land use permits for an additional 11 feet (3.4 m) on one side and 35 feet (10.7 m) on the other side of the right-of-way and for a 200 foot (61 m) space necessary for the construction of a haul road along the segment of the pipeline from Livengood to Prudhoe Bay. Environmental groups, alarmed by the potential danger that the pipeline posed to the Alaska tundra and wildlife, sought to block Federal approval of its construction on the grounds that the rights-of-way and special land use permits were in violation of the Mineral Leasing Act (MLA) of 1920 and the National Environmental Policy Act (NEPA) of 1969. In March 1970, conservation organizations filed suit against the Department of the Interior and won. Several Native groups, who sought to block right-of-way permits for the pipeline to cross village lands, were also granted an injunction against DOE permit approvals.

In 1972, the final environmental impact statement (EIS) on TAPS was completed. President Nixon then directed the Department of the Interior to immediately authorize the construction of the 800-mile (1 287-km) pipeline and haul road. Environmentalists appealed again solely on the basis of the 1920 MLA, which limited rights-of-way across public lands to a width of 50 feet (15.2 m). The US Supreme Court upheld the appeal. The only remaining alternative was for the President to seek congressional authorization for the pipeline, which changed the 1920 law and exempted TAPS from further provisions of NEPA. The 1973 Trans-Alaska Pipeline Authorization Act removed the 50-foot (15.2-m) right-of-way limit and barred any further pipeline challenges based on NEPA.

Construction subsequently began in 1974, and TAPS began transporting oil from the North Slope in June 1977.

Formation of the North Slope Borough

The concept of forming a regional government of the North Slope people was developed in the context of the land claims movement, when the prospect of a favorable settlement for the North Slope appeared dim. But the idea found support and soon existed

independently of the land claims struggle. In January, 1971, ASNA prepared petition forms and circulated them among the local people--the first step in the formal incorporation of a borough. Petitioners sought incorporation as a first-class borough in order to gain a home-rule charter. The Local Boundary Commission (LBC) held a hearing on the ASNA petition in Barrow in December 1971. In February 1972, the Local Boundary Commission unanimously approved the petition for establishment of a first-class borough with areawide powers of education, taxation, planning and zoning.

In March 1972, seven oil companies and five industrial firms filed a petition in the Superior Court in Anchorage for a judicial review of the findings of the Local Boundary Commission. The commission also moved for a summary judgement which would stay the holding of North Slope Borough incorporation elections. The Superior Court denied a summary judgement in June 1972.

In January, 1974, the Alaska Supreme Court rejected all arguments of the oil companies. But for its first year and a half of operation, the North Slope Borough operated without full legal sanction and with very little money, because the oil companies would not pay taxes until the Supreme Court reached a decision.

The Alaska Coastal Management Act

The Alaska Coastal Zone Management Act of 1977, provided for a coastal management program based on a partnership of State and local management. In early 1977, the North Slope Borough Planning Department initiated a local coastal management program for the Prudhoe Bay area. This plan was published in 1978. Because approval of the plan by the Alaska Coastal Policy Council looked doubtful before the Joint Federal/State Beaufort Sea Lease Sale, the borough engaged the public-interest environmental law firm, Trustees for Alaska, to draft recommended zoning ordinances based on the 1978 program. The aim of these ordinances was to regulate land and water uses at Prudhoe Bay until the program was approved. The borough zoning ordinance and ancillary documents and maps that evolved from this process became collectively known as the Mid-Beaufort Coastal Management Program.

Opposition to the Mid-Beaufort program by the oil and gas industry and critical reviews by several State agencies indicated that an approved Mid-Beaufort program would be impossible to implement without litigation. Therefore, the North Slope Borough withdrew the Mid-Beaufort Coastal Management Program from consideration on January 10, 1980.

The North Slope Borough is currently drafting a revised and expanded coastal management program. A draft of the program is scheduled to be produced on June 30, 1982 for public hearings. If this schedule is followed, the Alaska Coastal Policy Committee would approve or disapprove the program by December 20, 1982.

As part of the coastal management program, the borough is preparing a comprehensive land use plan. A draft of this plan was published in July 1981. The borough's coastal planning and zoning efforts also include a number of resource inventories and preservation plans.

The Joint Federal/State Beaufort Sea Lease Sale

The Joint Federal/State Beaufort Sea Lease Sale was the first in which OCS lands were leased in the Arctic. The sale was held under the joint authority of the State of Alaska and the US Department of the Interior because, although both the Federal and State governments wished to hold a lease sale in the Beaufort Sea, both claimed jurisdiction over certain tracts in the proposed lease area. These claims originated from conflicting interpretations of the correct method of defining the Federal/State boundary along the row of islands adjacent to Prudhoe Bay.

In November 1979, the North Slope Borough, the village of Kaktovik, and various environmental organizations filed lawsuits. The basic thrust of these suits was the conflict between subsistence activities and oil and gas development offshore. Requests for injunction of the lease sale were filed against Federal tracts in the Federal District Court for the District of Columbia and against State tracts in the Alaska Superior Court.

Injunctions were denied in both cases and the sale held on December 11, 1979, in Fairbanks. However, on January 22, 1980, the Secretary of the Interior was enjoined from accepting bids and issuing leases on the Federally managed tracts.

The district court injunction resulted from the findings that, among other things, the Secretary of the Interior had violated the National Environmental Policy Act (NEPA) because the final EIS failed to adequately assess cumulative impacts of the sale, alternative lease stipulations, and alternative management schemes and that he had violated provisions of the Endangered Species Act. To address the findings of the district court, a draft supplemental environmental statement was prepared in May 1980.

In July 1980, the injunction on bid acceptance was vacated by the Circuit Court of Appeals for the District of Columbia. Because the injunction was vacated, no final supplemental environmental statement was released.

Two other lawsuits resulting from the Joint Sale remain in litigation. The first suit was filed in December 1979 by the North Slope Borough, the village of Kaktovik and others. It concerns the validity of the Beaufort Sale beyond the barrier islands and is before the Alaska Supreme Court. The other suit still pending was filed in January 1981 by the Inupiat Community of the Arctic Slope, Barrow's village corporation, and certain individuals in the US District Court. This lawsuit alleges that the Inupiat people have full title, ownership, and dominion over the entire North Slope, including offshore areas beyond 3 miles (4.8 km). It charges the United States with infringement of tribal sovereignty, trespass and breach of trust.

The Alaska National Interest Lands and Conservation Act

On December 2, 1980, Congress passed the Alaska National Interest Lands Conservation Act (ANILCA) after nearly 4 years of intense debate. ANILCA designates new and expanded conservation system units throughout Alaska. It also addresses numerous issues that remained confused and unresolved as a result of ANCSA. Particularly pertinent to the North Slope, ANILCA designates the entire central Brooks Range as the Gates of the Arctic National Park and Preserve and makes a significant addition to an existing Arctic National Wildlife Refuge (ANWR). Section 1431 settles most of the outstanding issues concerning land entitlement of the Arctic Slope Regional Corporation (ASRC) and most North Slope Village corporations. One subsection permits an exchange of certain ASRC lands along the northern boundary of the Gates of the Arctic National Park for public lands within the Arctic Slope Region. Another subsection permits ASRC to obtain subsurface rights beneath village corporation lands within NPRA and ANWR.

Other issues addressed by ANILCA include giving the taking of fish and wildlife from Alaska public lands for nonwasteful subsistence use priority over the taking of fish and wildlife for other purposes. In the course of exercising this discretion, the State is required to consult with affected governments, including the North Slope Borough. In addition to these provisions, ANILCA directs the Secretary of the Interior to initiate numerous studies concerning land use issues.

Conclusions

As the previous section established, most of the oil and gas-related activity in the US Arctic has been subject to litigation. To a great extent, this litigation has been

due to the fact that each level of government (local, State, and Federal) wants to have the final word on land use. This situation is exacerbated by vastly different perceptions of land. The Inupiat society relates to land in ways that are vastly different from urbanized industrialized society. The Inupiat concepts are intense, having grown from generations of close interaction with the landscape. Subsistence is the highest priority use of land. The North Slope Inupiat also place an extremely high value on their freedom to move unimpeded over an open landscape. It is likely, therefore, that proposed changes in land use will continue to be subject to litigation. It is not clear to what extent the possibility of litigation has reduced the number of facilities that might have been sited on the North Slope. The high costs of transportation and construction in the Arctic have also played a part.

Most of the oil and gas-related facility location decisions on the North Slope have not been products of rigorous siting methodologies. The facilities at Prudhoe Bay are contained in an area of approximately 250 square miles (647 km^2), which measures about 20 miles (32.2 km) from east to west and 10 miles (16.1 km) from north to south. ARCO operates the eastern part of the Prudhoe Bay unit and Sohio operates the western part. The two operators use different terminology for the same types of facilities. This practice probably results from an attempt by the operators to maintain their own identities at Prudhoe Bay and the competitive nature of oil and gas operations there. The construction undertaken by Sohio also shows more European influence as a result of Sohio's relationship with BP.

The facilities currently at Prudhoe Bay include six flow stations (ARCO) or gathering centres (Sohio), a base camp for each operator at which employees are housed and from which field operations are controlled, over 150 miles (241 km) of gravel roads, two gravel docks, two airstrips, one central and several smaller power stations, a field refinery, and the shops and warehouses of contractors and service companies. ARCO drills wells from at least 17 drilling sites and Sohio drills from at least 15 drilling pads. A total of over 120 gravel pads have been constructed to accommodate buildings and drilling equipment.

The production structures called gathering centres by Sohio and flow stations by ARCO are designed to remove gas and water from 300 000 barrels ($47\,670 \text{ m}^3$) of oil per day fed from the wells through gathering lines. From the gathering centre, oil is passed to Pump Station 1 and through the Alyeska pipeline. Gas is routed to a gas compression plant operated by ARCO, in the northern part of the Prudhoe Bay area.

ARCO and Sohio maintain separate operations centres. These centres include recreation, dining, and sleeping areas, and sewage treatment facilities. Three additional construction camps have the capacity to house about 2 750 workers.

A small field refinery has been in operation in the ARCO operating area of the Prudhoe Bay Unit since 1969. This crude oil topping plant refines approximately 15 000 barrels (2384 m^3) of crude oil each day.

A number of new facilities are proposed for the Prudhoe Bay area. More attention was given to siting these facilities than was given to the siting of the facilities built earlier. A sales gas conditioning facility (SGCF) is being planned to condition natural gas from Prudhoe Bay for transportation through ANGTS. The facility will condition gas by removing carbon dioxide and heavy hydrocarbons, and by compressing and chilling the gas. The environmental impact statements for this facility were prepared by the Federal Energy Regulatory Commission (FERC, 1980). Both the draft and final environmental impact statements considered alternative sites for the SGCF, but this consideration was only cursory. Since FERC had selected a 1 260 psig pipeline system for ANGTS, which required that most heavier molecular-weight hydrocarbons be removed from the unconditioned gas stream at Prudhoe Bay, none of the six alternative sites were feasible from an engineering standpoint. In addition, several of the alternative sites were not realistic because there was not an adequate transportation network to carry construction material and personnel to the site. However, the final EIS did consider a number of measures to avoid or mitigate adverse environmental effects of the proposed SGCF at Prudhoe Bay.

The other major project proposed for Prudhoe Bay is the waterflood project. It calls for 2.2 million barrels ($349\,580 \text{ m}^3$) of seawater and 1 million barrels ($159\,900 \text{ m}^3$) of produced water per day to be injected into the formation to retrieve an additional 1 billion barrels ($158\,900\,000 \text{ m}^3$) of oil from the field. The waterflood project consists of several facilities: an offshore seawater intake facility; a pipeline and supporting gravel causeway; and two onshore injection plants. The final environmental impact statement was released early in 1981 (US Army Corps of Engineers, Alaska District, 1980). The EIS considered only two alternatives to accomplish waterflooding, these were ARCO's proposed project and an environmentally preferred alternative.

The State of Alaska would have liked the environmentally preferred alternative to have been implemented. But the pre-construction engineering work had been conducted only for ARCO's proposal. The time needed to conduct similar

engineering for the environmentally preferred alternative would have delayed the project for over a year. Therefore the State accepted ARCO's proposal with some modifications. As a result, however, the State made an important policy decision. Henceforth, the State will require that engineering work be carried out for at least two of the alternatives presented in an EIS.

The future siting of energy-related facilities will be determined by a number of factors. The decisions given in the two pending Beaufort Sea land use cases could resolve many of the issues surrounding the siting of facilities by determining which level of government has the most power in land use decisions.

The North Slope Borough's Coastal Management Plan will also play a major role in determining how energy-related facilities are sited on the North Slope. Early drafts of their coastal management program indicated that a petroleum production district would not be allowed in most areas. A less restrictive program is expected to be presented to the State during the summer of 1982. Currently the borough is experimenting with an automated geographic information system. This GIS (Environmental Systems Research Institute and Arctic Slope Technical Services, Inc., 1982) provides a detailed (approximately 1 inch = 1 mile) series of data maps relevant to siting, as well as mapping and analysis capabilities. A unique feature of the system is an automated review and comment system, which combines a digitized data base and defined responses and policies to formulate and document consistent responses to development proposals. The system is flexible so that additional comments can be added, but the ways in which policies and comments are specified would be useful to siting as well as the review process.

The borough hopes that this system will enable them to develop a more flexible comprehensive land use plan, as well as a coastal zone management plan that will be acceptable to the state.

Another recent study (Dames & Moore, 1982) for the Alaskan Arctic has examined the costs and benefits of stipulations, particularly seasonal drilling restrictions, on oil and gas exploration. Although the study did not deal with siting, it did require a diverse group to consider the relative importance and susceptibility of different species, the relative likelihood of different effects and the variation of effects over time. (These items are important in the siting process and the criteria we have proposed.) The approach used a modification of the weighted summation technique.

The study also indicated the infeasibility of a total cost-benefit approach. Although costs of each alternative stipulation were determined and benefits of each

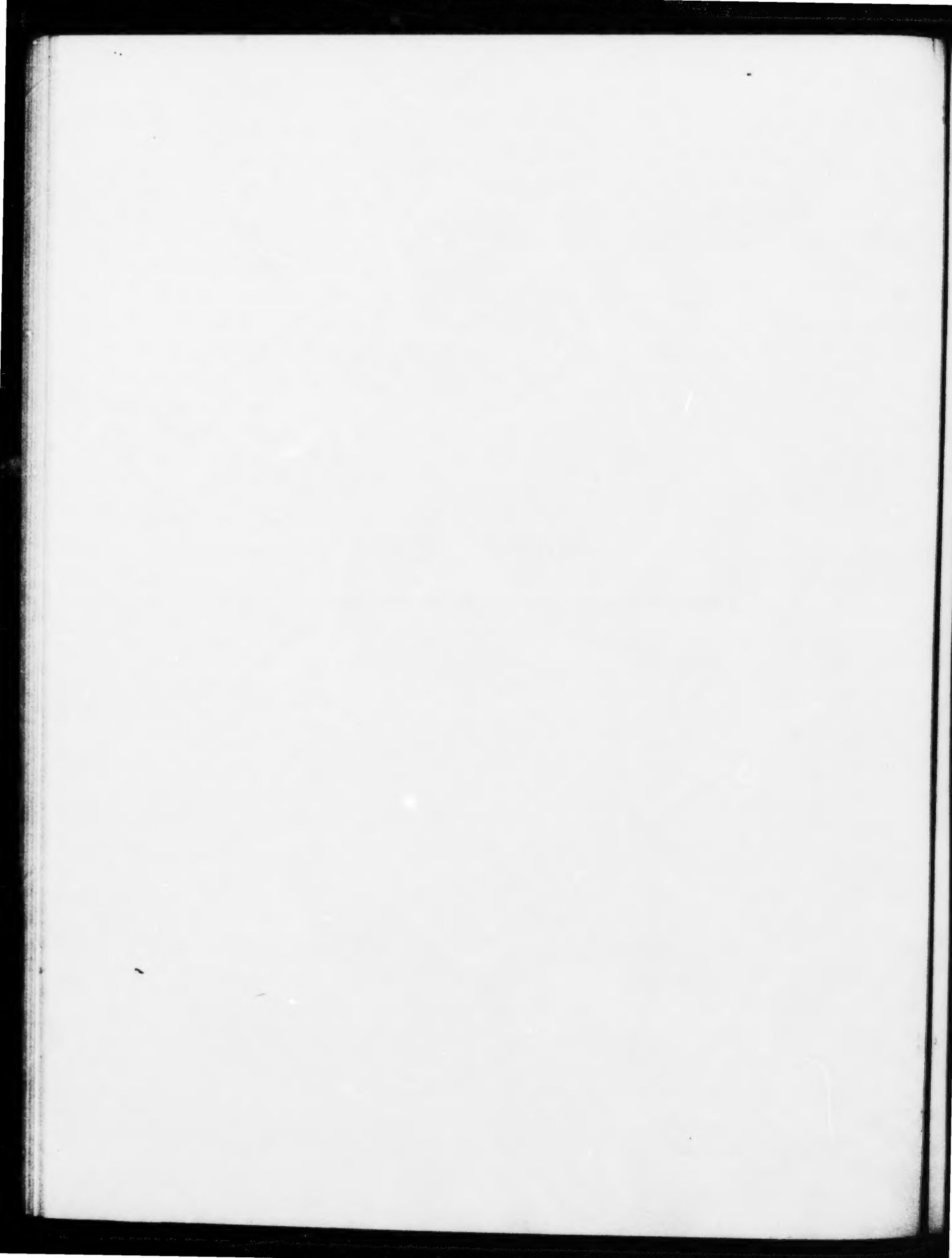
stipulation were ranked on a relative scale, there was no way to compare costs and benefits on the same basis.

The information in this appendix indicates that issues in siting and trade-offs of environment and economics have not been resolved in the US Arctic. Siting is highly political and the respective roles of the different levels of government are unresolved. Settlement of important issues, including siting, without full participation of the Native people, would be unrealistic.



APPENDIX II

A WORKED EXAMPLE OF THE SITING PROCESS



APPENDIX II

A WORKED EXAMPLE OF THE SITING PROCESS

This appendix provides a worked example of the siting process. For purposes of illustrating its application, the example is simplified so that the process can be followed easily. Specifically, only two fictitious participants are considered; the region of interest and its characteristics are fictional and generalized; and only steps that are necessary to explain the workings of the process are included in the example. No actual mapping or combination of criteria was performed as a basis for the example. The "maps" that are provided are schematic, illustrating the concepts of the process.

The basis of the example is the siting of a shorebase somewhere on the Beaufort Sea coast. The participants in the process are Canaco Oil Limited, the proponent, and the Arctic Fox Village Corporation, which represents the Native's interests in the area likely to be affected by development. The principal Native settlement, where the corporation is headquartered, is the village of Arctic Fox. The general locations of the village, the coast and the principal exploration area (shown by well symbols) are shown in Figure A.

Step 1g

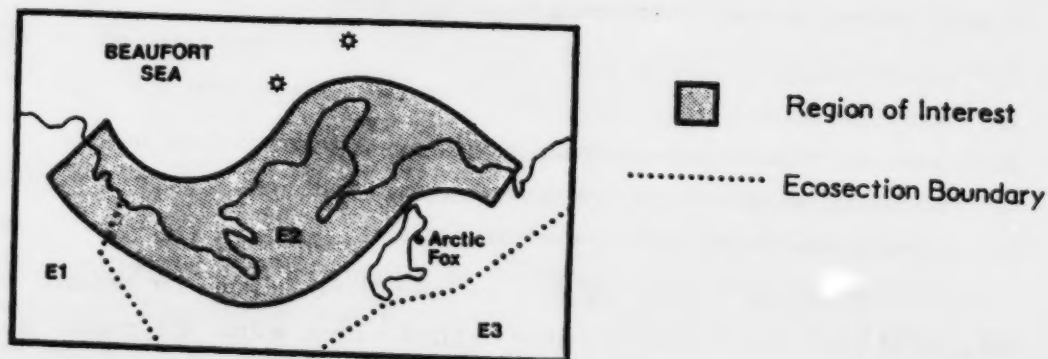


FIGURE A DETERMINATION OF THE REGION OF INTEREST

The proposed facility requires access to 18-foot (6 m) water depth and 200 acres (80 ha) of relatively flat land at or near the shore. Possible future expansions of the facility to 1000 acres (400 ha) include an airstrip, a dry dock, gravel storage and staging areas for offshore construction, so that more flat land and deep water are advantageous. The primary effects of the facility will be in opening a currently undisturbed area for an expanding facility complex, dredging, and the need for air and road access year-round.

In order to determine a reasonable region of interest for siting the shorebase, the primary considerations are available water depth, distance from the current exploration (and possible future production) area, location with respect to the village, and environmental diversity. Diversity is represented in the example by ecosections. Only coastal areas are considered.

After considering the above factors the participants agree on a region of interest, as shown in Figure A. The region extends to the west enough to include a reasonable area from ecosection E1—a plain somewhat drier than the delta-related deposits of E2. Going farther west is undesirable because of distance from the resource area. Ecosection E3 only occurs inland. A comparable distance, as well as locating away from Arctic Fox, limit the region to the east.

After considering its objectives of maintaining a subsistence lifestyle and traditional culture and protecting Native land claims, the village corporation determines that five criteria adequately represent these objectives:

1. primary trapping areas for Arctic fox;
2. waterfowl hunting areas;
3. proximity to the village and traditional access routes;
4. traditional whale and seal subsistence hunting areas; and
5. primary subsistence areas for caribou.

All of the criteria are examined and found suitable for regional screening. Because of their significance and their limited extent within the region of interest, Criteria 4 and 5 are applied as exclusion criteria. The other criteria are grouped as follows into appropriate levels that can be mapped using available data.

Criterion 1 - Primary trapping areas for Arctic fox

- Level A - areas not usually trapped for fox
- Level B - areas historically trapped or containing Arctic fox habitat but subject to

- low yield
- Level C - principal traplines and high-yield trapping areas
- Criterion 2 - Waterfowl hunting areas
- Level A - areas of low density of waterfowl or occurrence of less important species
- Level B - areas of low density or limited hunting success for important species
- Level C - prime subsistence hunting areas for important waterfowl
- Criterion 3 - Proximity to villages and traditional access routes
- Level A - locations remote (20+ km) from the village and access routes
- Level B - locations remote from the village but conflicting with access routes
- Level C - locations within 5 km overland of the village

All these criteria have been arranged and coded so that level A is the most suitable, B is intermediate and C is least suitable.

The process used to determine the portion of the region of interest that the Natives would find most acceptable for the facility is shown in Figure B. A goal of finding the best 5% of the region of interest is set based on the resources available to conduct the siting study. The four parts of Figure B-2 accomplish the following.

Part I. The project manager (an environmental engineer with Canaco) and his support staff assemble the data, map the criteria, overlay the maps and prepare the statistics shown. Only nine of 27 possible combinations occur.

Part II. The project manager and staff compare the combinations and their frequency of occurrence to determine if any combinations are clearly part of the best 5% or not part of it. This analysis is based only on knowing the preferences among levels within each criterion, with no information as to the relative importance of levels and criteria combined. Clearly Combination 1 (AAA) is the best 1% of the siting region and part of the top 5%. Other combinations are compared to determine the percent inferior to them, percent superior to them and the percent whose inferiority or superiority cannot be determined. For example, BCA, CBB, BBC and CCC are inferior to BAA. These account for 77% (27% + 46% + 2% + 2%) of the region. Therefore, 77 is entered in the "% of the siting region that is inferior" column for Combination 3. This analysis is repeated

I Step 2o

98

Combination	Level for criterion			% of siting region
	1	2	3	
1	A	A	A	1
2	A	B	A	1
3	B	A	A	1
4	A	A	B	10
5	A	C	A	10
6	B	C	A	27
7	C	B	B	46
8	B	B	C	2
9	C	C	C	<u>2</u>
				100

II Step 2p

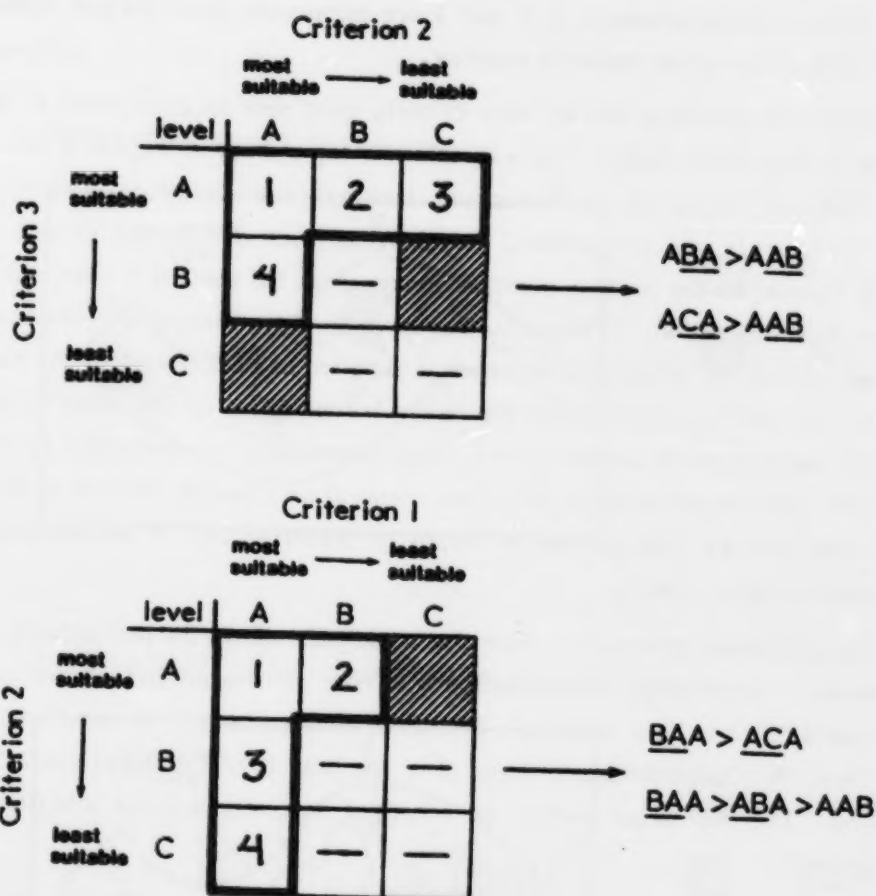
n = 5%

Combination	Level for criterion			% of siting region that is		
	1	2	3	inferior	superior	?
1	A	A	A	99	0	0
2	A	B	A	87	1	11
3	B	A	A	77	1	21
4	A	A	B	50	1	39
5	A	C	A	29	2	59
~~6~~	~~B~~	~~C~~	~~A~~	~~2~~	~~13~~	~~58~~
~~7~~	~~C~~	~~B~~	~~B~~	~~2~~	~~13~~	~~39~~
~~8~~	~~B~~	~~B~~	~~C~~	~~2~~	~~13~~	~~83~~
~~9~~	~~C~~	~~C~~	~~C~~	~~8~~	~~98~~	~~8~~

Lined out combinations are eliminated because more than 5% of the region is superior

FIGURE B

A WORKED EXAMPLE OF TECHNIQUES TO SELECT CANDIDATE AREAS USED IN STEP 2



IV Step 2u

Combination	Level for criterion			% of siting region that is			?
	1	2	3	inferior	superior	equivalent	
1	A	A	A	99	0	1	0
2	A	B	A	97	2	1	0
3	B	A	A	98	1	1	0
4	A	A	B	50	13	10	27
5	A	C	A	87	3	10	0

FIGURE B

A WORKED EXAMPLE OF TECHNIQUES TO SELECT CANDIDATE AREAS USED IN STEP 2 (Continued)

to fill the table. Combinations 6, 7, 8 and 9 are eliminated from further consideration because 13-98% of the siting region is superior.

Part III. Trade-offs involving two or more criteria must now be considered to determine the best 5% of the siting region. For example the top matrix of Figure B (III) considers trade-offs between Criterion 2 (Waterfowl hunting) and Criterion 3 (Proximity to villages). To simplify the comparison, combinations such as CB that do not occur are shown cross-hatched on the matrix; combinations such as BB that have been eliminated in Step 2p are shown as a line. Trade-offs that have to be considered are emphasized by a heavy border. All of the printed information is supplied as background to the participant, who numbers the combinations within the heavy border in his or her order of preference (shown by the hand-lettered numerals 1-4). This information is interpreted by the project staff to reach conclusions such as ABA (the corporation's second choice) is preferred to AAB (its fourth choice). The symbol ">" means "is preferred to." A similar comparison is made between Criteria 1 and 2.

Part IV. The additional information from the trade-offs allows the percentages from Part II to be revised. Accordingly, Combination 4 is now eliminated and all the uncertainty (column headed "?") has been resolved. The areal distribution of the combinations allows either the best 3% (Combinations 1, 2 and 3) or the best 13% (Combinations 1-3 and 5) to be identified. The 5% target cannot be achieved precisely without additional data or screening criteria.

A similar exercise is carried out for the industry participant, using criteria such as amount of construction or dredging to 18-foot water, shore terrain, distance from exploration wells, harbour protection, and duration of landfast ice. The results for each participant are shown in Figure C.

The separate maps in Figure C are compared according to the rules of Step 3, and from the resulting candidate areas, three potential sites (S1-S3) are identified as suggested in Step 4 and shown in Figure D.

For selecting sites the rankings are as follows:

	<u>Canaco Oil Ltd.</u>	<u>Arctic Fox Native Corporation</u>
1st	S2	S1
2nd	S1	S3
3rd	S3	S2

Steps 21 and 2w

PARTICIPANT NO. 1: Industry



PARTICIPANT NO. 2: Local Native Organization

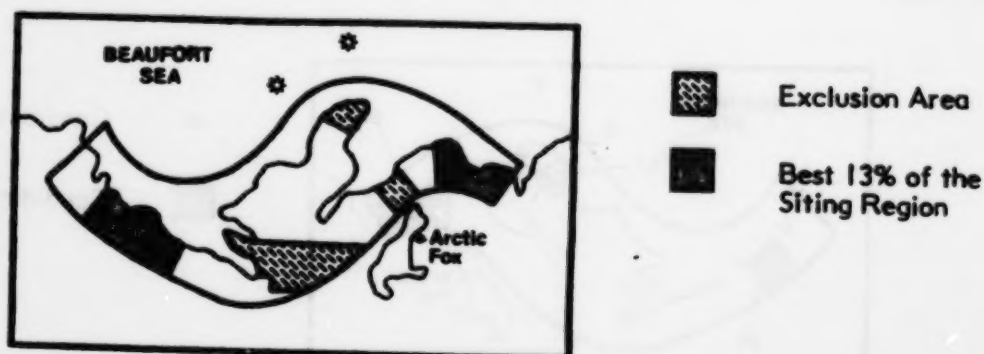


FIGURE C DETERMINATION OF SPATIAL PREFERENCES FOR EACH PARTICIPANT

S2 is logically preferred by Canaco since it is in an inclusion area. S2 is ranked lowest by the Native corporation because it abuts an exclusion area. S1 represents the best chance for a compromise and upon closer examination, it is selected. The site requires no dredging because of deeper water near shore, although it is much farther from the exploration sites. The site is far enough from the village and of low enough importance to subsistence that it was preferred by the Natives of Arctic Fox. To satisfy the Native corporation, S2 would have required major stipulations on the construction and operation seasons and the ultimate scale of development; and hence it was rejected during negotiations with the Northern Land Use Committee acting as an arbiter.

The example illustrates the general flow of the process dealing with all its permutations or subtleties.

Steps 3 and 4

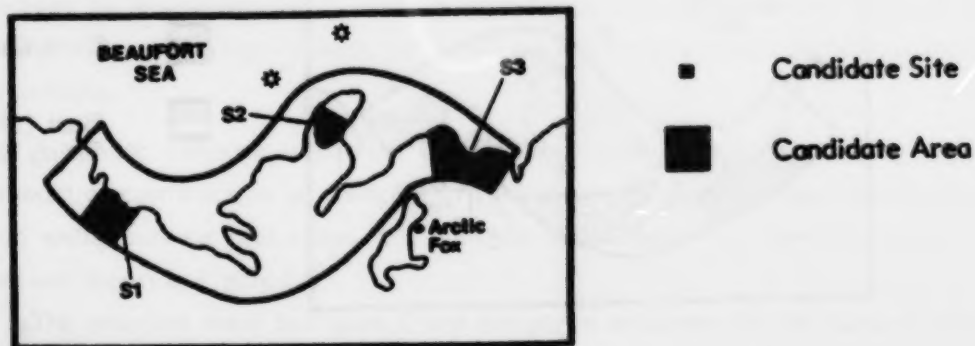


FIGURE D

SELECTION OF CANDIDATE AREAS AND CANDIDATE SITES

APPENDIX III

A SUMMARY LISTING OF ENVIRONMENTAL CRITERIA

APPENDIX III A SUMMARY LISTING OF ENVIRONMENTAL CRITERIA

This appendix contains a listing of example criteria for siting hydrocarbon facilities on the Canadian Arctic Coast. The listing is arranged under considerations (bold type) as principal categories. Issues or more specific considerations form the next level of the hierarchy. Example criteria (bulleted items) are the most specific level. The main text provides an explanation of the selection, application and significance of these criteria. The listing contains additional related examples, which are not discussed in the report.

1. *Terrestrial Ecology*

Parks, Reserves and Natural Areas

- National and Territorial Parks
- Wildlife Areas and Sanctuaries
- Reserves
- Natural Areas of Canadian Significance (NACS)
- Natural Sites of Canadian Significance (NSCS)
- International Biological Program (IBP) Sites
- Areas of Wildlife Significance
- World Heritage Natural Sites
- UNESCO's Man and the Biosphere (MAB) Program

Rare, Endangered and Endemic Species or Communities

Known occurrences of or optimal habitat for wildlife with designated status including:

- barren ground grizzly;
- Peary caribou;
- Eskimo curlew;
- Arctic peregrine falcon;
- barren ground caribou;
- musk-ox; and
- polar bear.

Incidence of endemic plant communities including those of unglaciated arctic areas in the Yukon Territory.

Critical Wildlife Habitats

Important habitats and functional areas for terrestrial mammals including:

- caribou calving, overwintering and insect relief areas;
- caribou migration routes;
- Arctic fox denning areas; and
- polar bear onshore/barrier island denning areas.

Important habitats for birds including:

- nesting, molting, staging, and feeding areas for waterfowl and other birds, such as geese, whistling swans, loons, ptarmigan, Arctic terns, shorebirds, ducks (dabbling and diving);
- raptor habitats;
- nests of gyrfalcons, eagles and hawks; and
- sightings of eagles.

Distribution and Density of Important Animal Species

Limits of distribution (summer/winter) and density of:

- moose, Dall sheep, grizzly bears, polar bears, Arctic and red foxes, wolves, caribou and other important mammals; and
- ducks, geese, whistling swans, shorebirds, Arctic terns, loons, ptarmigan and other birds.

Sensitive Plant Communities

Plant communities sensitive to air pollution (e.g., lichen) or disturbances associated with development.

Productive Ecological Communities

Areas of high primary productivity such as floodplains and deltas.

Areas of vegetation cover in areas with little continuous cover.

2. *Aquatic Marine Ecology*

Parks, Reserves and Natural Areas

Areas protected or nominated for protection because of their aquatic or marine resources such as:

- Marine Natural Areas of Canadian Significance;
- International Biological Program (IBP) Sites; and
- Marine Areas of Interest.

Aquatic or marine parts of protected or "nominated-for-protection" areas such as:

- Natural Sites of Canadian Significance; and
- IBP Sites.

Rare and Endangered Species

Optimal habitat and concentrations of bowhead whales.

Critical Habitats

Areas important to aquatic and marine life for:

- migration (whales);
- egg incubation;
- spawning (whitefish, burbot, Arctic cisco, boreal smelt, Arctic char);
- overwintering (fish including whitefish, grayling, Arctic char and four-horned sculpin);
- calving (beluga and bowhead whales);
- pupping (ringed and spotted seal); and
- offshore denning (polar bears).

Productive Ecological Communities

Areas of high marine productivity including interfaces of arctic and sub-arctic waters.

Concentrated feeding areas of fish, marine mammals and birds.

Freshwater lakes.

3. *Socio-cultural Resources*

Inuit and Dene Settlements

Proximity to Native permanent communities, campsites and traditional settlements.

Size and population of settlements.

Existing access to settlement.

Disruption of local economy.

Sites of Symbolic, Cultural or Religious Significance

Native lands claims.

Sites of Historical or Archeological Significance

Traditional land use inventory sites.

Sites nominated for historical status.

Recreation and Tourism

Natural, landform or lifeform landmarks.

Outstanding wilderness resources areas.

Primitive recreation opportunities for:

- backpacking, hiking and camping;
- boating, including floatboating;
- big game hunting;
- waterfowl hunting;
- cross-country skiing;
- mountain climbing;
- nature viewing; and
- sports fishing;

4. *Subsistence Economy Effects*

Subsistence Hunting Areas

Primary (secondary) subsistence use areas for hunting whales, seal, walrus, polar bear, caribou, wildfowl, musk ox, grizzly bear, wolf, wolverine, sheep.

Trapping Areas

Fox trapping areas.
Muskrat trapping areas.
Other trapping areas.
Traplines.

Subsistence and Commercial Fishing Areas

Primary (secondary) subsistence fishing areas.
Commercial fisheries.

Other Subsistence Use Areas

Fuel and structural material gathering areas.
Berries and edible plant gathering areas.

5. *Hydrologic Effects*

Flooding

Areas below coastal surge elevations for various return periods.
Riverine floodprone areas for various frequencies of occurrence.

Erosion

Areas subject to thermokarsting, gullying, slumping or permafrost-related erosion.
Areas of high coastal erosion.

Water Quality/Surface Water Use

Proximity to water bodies used for domestic water supply.
Areas upstream of domestic water supplies.

6. *Climatology*

Air Quality

Landforms such as deep valleys subject to atmospheric inversions.

Ice Cover and Movement

Concentrations of ice and patterns of ice drift.
Consolidated ice edges.
Location of the grounded ice ridge zone.

Known areas of high ice scour.

7. Non-renewable Resources

Mineral and Non-mineral Resources

Known mineral occurrences including coal, lead, zinc, barite.

Favorable geology or mineral resource potential.

Sand and Gravel

Known sand and gravel deposits of economic size including building stone deposits.

Potential sand or gravel resources.

8. Terrain/Ecological Land Classification

Ecosections

Environmental suitability of ecosections or of specific parameters of ecosections such as:

- genetic materials;
- surface expression;
- textural modifier
- percent cover;
- vegetation;
- lake characteristics;
- river characteristics; and
- drainage pattern.

Biotic significance inferences from ecosections.

Landform/Surface Form/Topography

Inferred environmental suitability and biological values associated with specific terrain features such as pingos, dunes etc.

APPENDIX IV

SITING PROCESS FLOWCHART



FIGURE 1 SITING PROCESS FLOWCHART

1. The first part of the report
describes the general situation
of the country.

2. The second part of the report
describes the general situation
of the country.

3. The third part of the report
describes the general situation
of the country.

4. The fourth part of the report
describes the general situation
of the country.

5. The fifth part of the report
describes the general situation
of the country.

6. The sixth part of the report
describes the general situation
of the country.

7. The seventh part of the report
describes the general situation
of the country.

8. The eighth part of the report
describes the general situation
of the country.

APPENDIX IV

SITING PROCESS FLOWCHART

The following flowchart (Figure 1), illustrates the steps of the siting process.

I. Define the siting problem

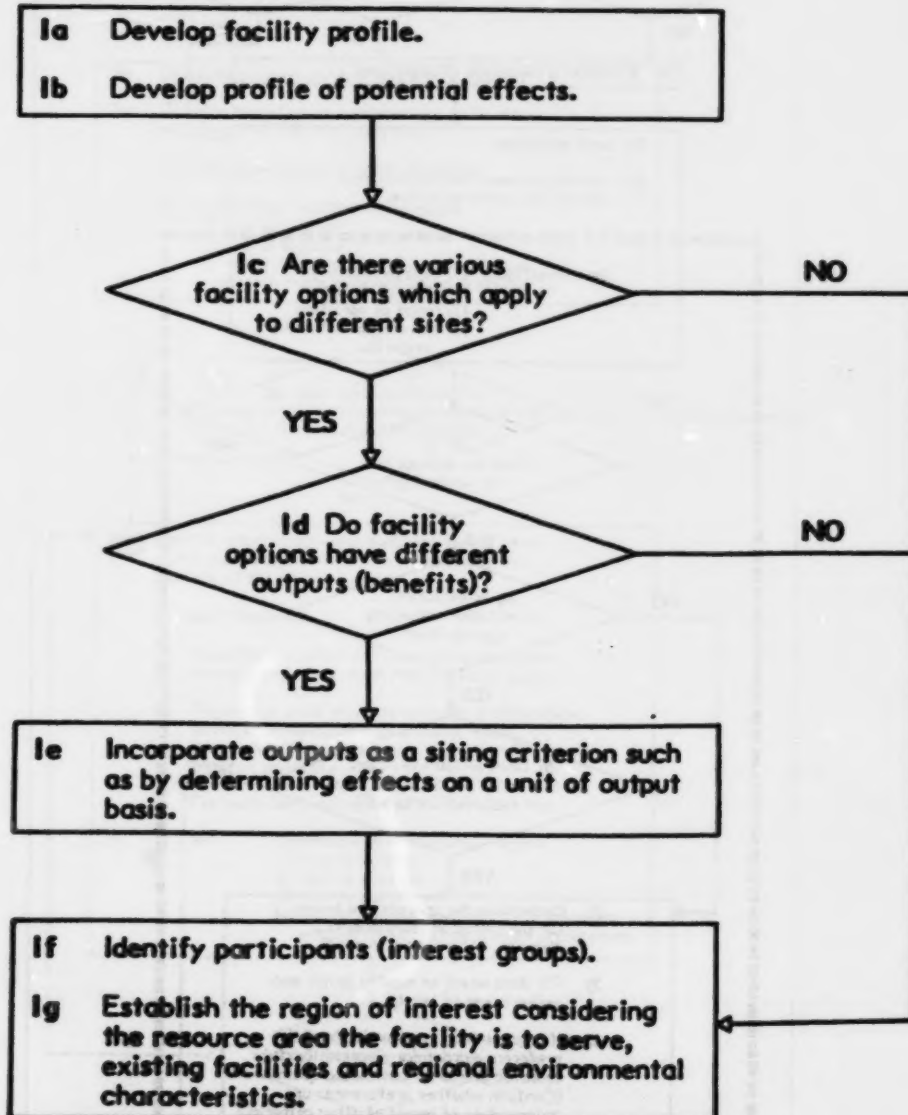
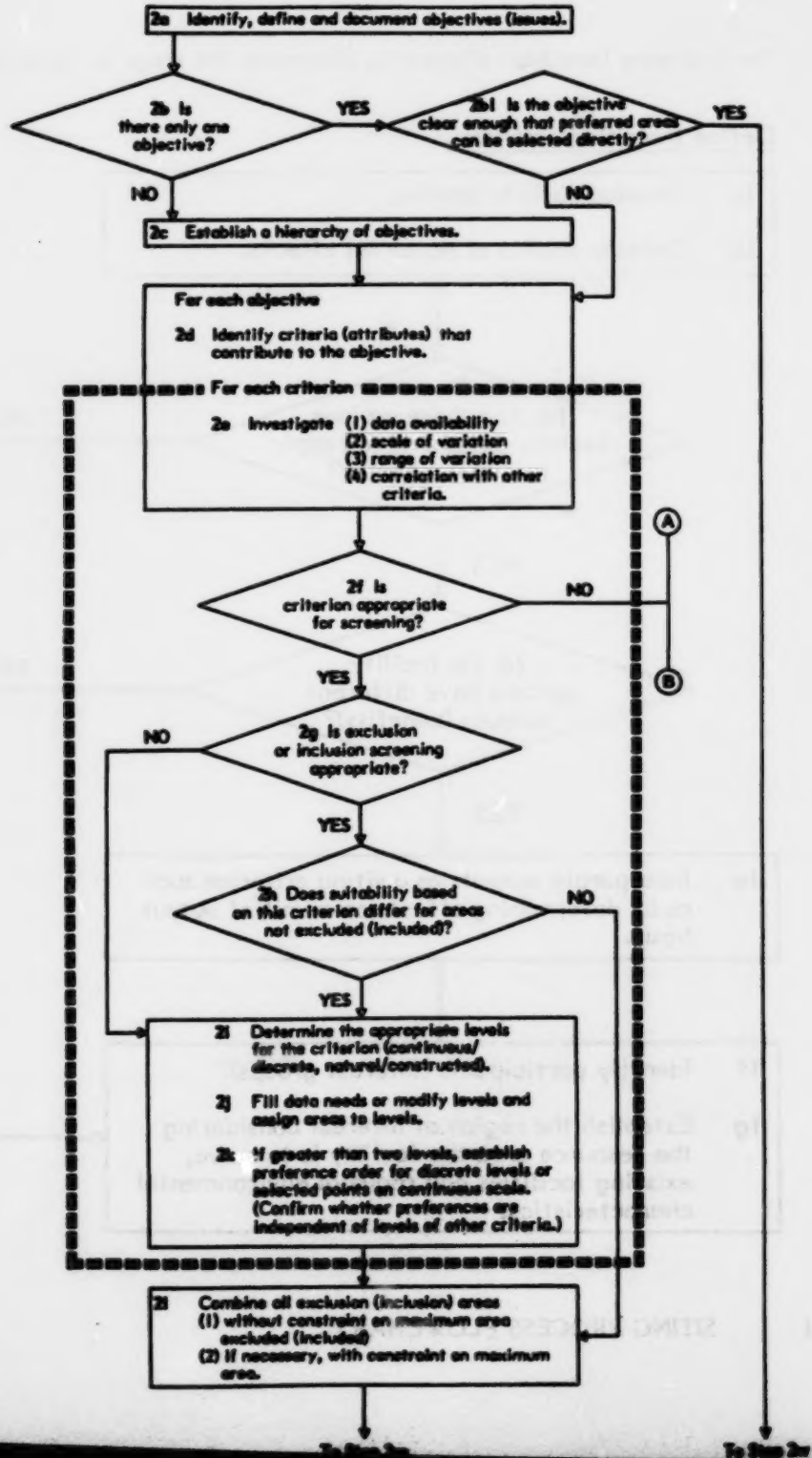


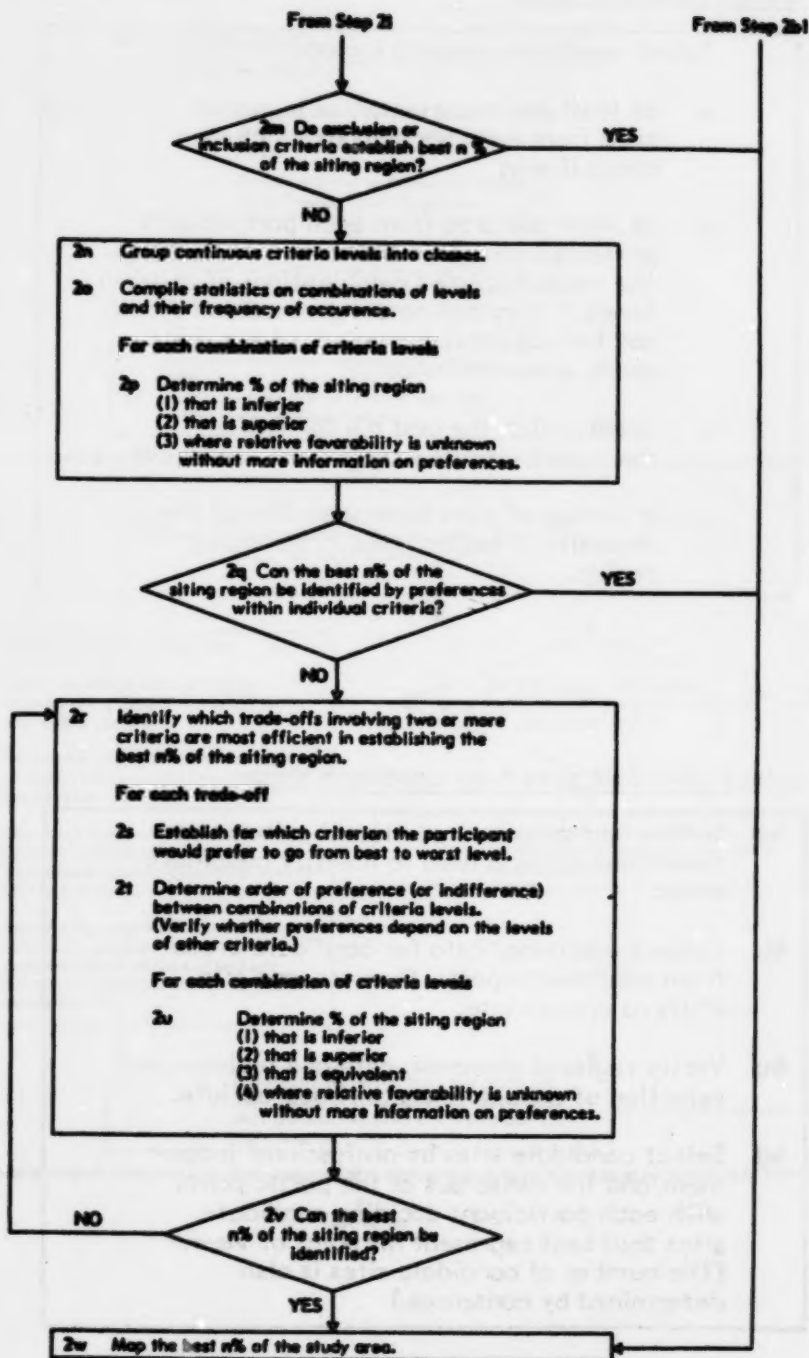
FIGURE 1

SITING PROCESS FLOWCHART

2. Translate regional screening issues to spatial preferences

For each participant





3. Select candidate areas

Select candidate areas to include

- o at least one representative inclusion area from each participant's inclusion areas if any;
- o at least one area from each participant's preferred n%. This area should include the most preferred combinations of criteria levels if they can be determined and should not include other participants' exclusion areas unless unavoidable;
- o areas within the best n% for two or more participants where these occur; and
- o a variety of sites representative of the diversity of better sites in the siting region.

4. Select candidate sites from candidate areas

(A)

- 4a Define and document additional criteria and reexamine criteria used to identify candidate areas.
- 4b Collect additional data for candidate areas from published reports, flyovers, and site visits as appropriate.
- 4c Verify regional screening data and revise selection of candidate areas if appropriate.
- 4d Select candidate sites by professional judgment and the consensus of the participants with each participant deciding candidate sites that best represent his point of view. (The number of candidate sites is also determined by consensus.)

5. Select preferred site(s)